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ABSTRACT

This guide is one of three teacher's guides developed for the U.S. Geological Survey's Water Resources Education Initiative. Each guide supplements a set in the accompanying poster series which forms the core of this project. This guide covers navigating the water highways, groundwater, and water quality and helps teachers use the included Water Resources posters by providing background material and 12 activities that draw from or build on the poster series. In addition to background information about navigation, ground water, and water quality, the guide contains a discussion on how students can protect water, ideas for further student research, and a list of related resources. The 12 activities are hands-on explorations that involve students in a variety of environmental education topics. Two sets of posters accompany this guide, one for middle school and one for elementary school. (DDR)

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# WATER MATTERS

## WATER RESOURCES TEACHER'S GUIDE VOL. 2

ED 410 103

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National Science Teachers Association

# Introduction

## *Getting Started*

Your students know a lot about water: its feel, its taste, its flow through our planet's water cycle, and its importance to living beings. This is a good start, but don't let it end here. Much about water lies hidden—literally and figuratively—under the surface. If you used the Water Resources posters bundled with *Water Matters, Volume 1*, your students had a solid introduction to general water use, wastewater treatment, and wetlands. In *Volume 2*, this under-the-surface introduction continues with attention to navigation, ground water, and water quality.

Earth's systems—life, water, rock, and gases—interact to create a wondrous planet. Help your students appreciate the economic and aesthetic importance of the hydrosphere and other Earth systems. Although your students interact with water every day, they may not realize how crucial these systems are for life on Earth, and they may not know much about how these systems work. For example, students may not know that waterways are central to the world's transportation system, or that they are the most common (and sometimes the only) means of transportation in some places. Likewise with ground water, your students probably don't know about the tremendous volume of fresh water present underground, or realize the extent to which they rely on that water being there. And when it comes to water quality, most will have a basic idea about what makes water clean or dirty. However, few will know much about the many ways water can be polluted, what such pollution means for them, or how they stop it.

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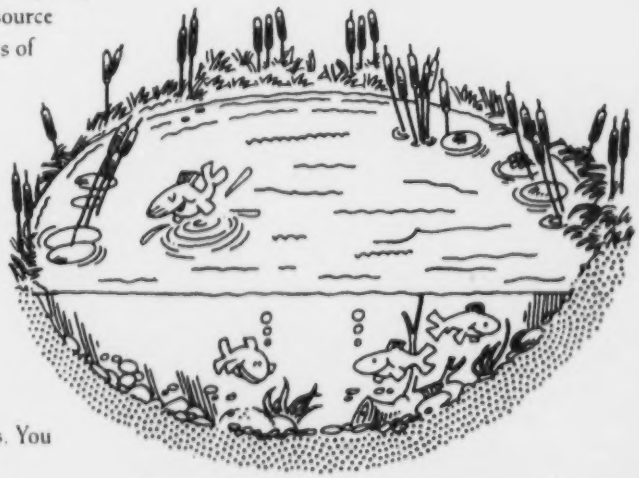
## *How To Use This Teacher's Guide*

*Water Matters, Volume 2* is one of three teacher's guides developed for the U.S. Geological Survey's *Water Resources Education Initiative*. Each teacher's guide supplements one of the rows in the poster series (Figure 1). This volume covers:

- Navigation: Traveling the Water Highways
- Ground Water: The *Hidden* Resource
- Water Quality: Potential Sources of Pollution



*Water Matters* serves several functions. It helps you use the Water Resources posters by giving you background information. It's a resource encouraging you in additional directions and connecting you with superb resources in water education. This guide is also intended to fuel your imagination when designing lessons. You will find 12 full activities and many

| Oceans | Watersheds | Hazardous Waste |
|---|---|---|
| Wetlands | Water Use | Wastewater Treatment |
| Navigation | Ground Water | Water Quality |

**Figure 1**
Subjects of posters in *Water Resources Education Initiative.* (Shaded row represents posters treated in this volume.)

extensions drawing from and building on the poster series. These materials will help make teaching about water easy, constructive, and fun. Whenever possible, get your students outside to experience their local environment. Pick up the rocks, watch the clouds, and talk about the native plants and animals. Teach to your passion. If you love biology or geology, let it show. Excitement is contagious—you get it from a teacher!

## *Making Connections*

One exciting aspect of the Water Resources posters is their connectivity. Each row of posters fits together to create a mural. This design helps remind us of the integral role water plays in our lives and in our environment. How water is used in one place affects its quality and supply far away. Hanging these posters together will help students build this larger picture. Too often larger systems are understood by students only as a collection of parts. A faucet draws water from a well; a heavy rain washes pollutants off the street. Students need to understand that these events can be related: pollutants from the street might flow into the water supply that feeds the well! One goal of the *Water Resources Education Initiative* is to reinforce these connections.

You may wonder if water is the only thing these three posters have in common. They are also tied together by the ground, the air, the animals, and the plants for whom water is vital. Each of these systems interacts with the others, creating a single Earth system. Use this teacher's guide to show your students how the hydrosphere—the planet's water network—interacts with the lithosphere (solid Earth), the biosphere (plants and animals), and the envelope of gases that composes the atmosphere. Use these colorful posters to help your students understand how Earth's systems depend on each other to provide necessities such as clean water, fresh air, and food. Understanding this interaction and appreciating Earth's resources are the first steps in generating a stewardship ethic.

Good water education requires thinking beyond the concept of water itself. Side trips into other sciences are essential. Investigating ground water, for example, is as much a study of geology as it is a study of water's liquid properties. Studying navigation means knowing about technology and geography. Water flow is a matter of physics; water quality a matter of chemistry; dams and canals are the domain of engineers and architects. Don't forget the atmosphere (meteorology), the seas (oceanography), plants and animals (biology), and their interconnections (ecology). As much as possible, encourage students to keep their learning about water integrated. This theme is developed throughout *Water*

**About the Water Resources Poster Project**

The Water Resources poster project was developed through the *Water Resources Education Initiative*, a cooperative effort between public and private education interests coordinated by the U.S. Geological Survey. In total, nine topical posters will be created, each based on one water theme. Three volumes of Water Matters will be developed to add background information and activity suggestions.

Partners in the *Water Resources Education Initiative* include the U.S. Geological Survey and the U.S. Fish and Wildlife Service of the U.S. Department of the Interior, the National Science Teachers Association, the U.S. Army Corps of Engineers, the U.S. Environmental Protection Agency, and the Groundwater Foundation.

*Matters* by providing a concrete example of integrated curriculum in science. The book links subjects from several disciplines by merging them into single lessons. Ask frequent questions about connections: How does a change here affect what happens elsewhere? What happens down stream as a result of water use up stream? How do the parts fit together into a system? Use these connections as a way to integrate the various sciences and other disciplines useful in this study of water.

Learning with an integrated curriculum means students develop many skills at once. When using the Water Resources posters, students will have many opportunities to measure, figure, and graph. You can enhance their calculation and data presentation skills. Ask them, for example, to create several kinds of graphs from the same data sets and compare the results. They'll use many kinds of measuring skills and may encounter the need for conversions (always convert to metric). They'll develop map-reading skills. They'll want to know where different places are located. They'll ask to search the Internet for more information. They'll find stories and poems on water-related themes. Water topics will seem to spring from just about everywhere!

# Navigation: Traveling the Water Highways

Ever sit by a river and quietly watch it move past? Flowing waterways are beautiful to watch. Rivers have been inspirations for artists, poets, and writers. Calm, gentle streams encourage peaceful contemplation. Gushing rapids and falls leave us in awe of nature's power. Rivers, lakes, and oceans evoke powerful feelings and add special value to our lives. These feelings are important to encourage: they reinforce students' commitment to conserve and protect these environments.

Rivers, lakes, and other waterways connect many parts of our history. The 1804 Louis and Clark expedition is a familiar example. Their across-the-continent-and-back expedition took three years, with much of their traveling on waterways. As they explored the Louisiana Territory, they made preliminary maps, surveyed the territory for its economic potential, and encountered many indigenous peoples. (Some of what they experienced is recorded in their expedition journals, which can make exciting reading for adventurous students.)

To the aesthetic and historical, add the practical. Rivers, lakes, and oceans have long been vital parts of the planet's transportation networks. Several thousand years ago, Egyptians floated barges down the Nile to move stone blocks for the great pyramids. The Inuit have used kayaks to move families and provisions through icy arctic waters. And during the last century, steamboats traveled on the major rivers of the world, carrying raw materials, manufactured products, and people. The world continues to rely on water highways—ships transport tens of billions of dollars in goods across waterways each year.

Data Box 1

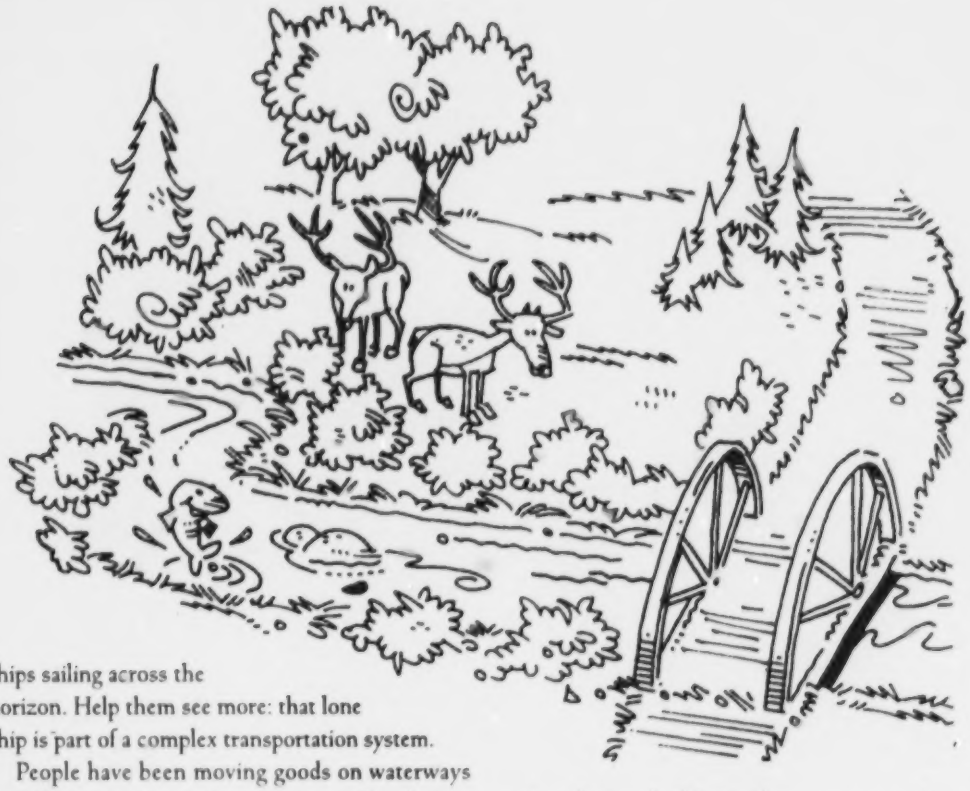
**Earth's Longest Rivers**

| River | Length (km) |
|---|---|
| Nile | 6,650 |
| Amazon | 6,400 |
| Yangtze | 6,300 |
| Mississippi-Missouri | 6,020 |
| Yenisey | 5,540 |
| Ob-Irtysh | 5,410 |
| Paraná | 4,880 |
| Congo | 4,700 |
| Lena | 4,400 |
| Mackenzi | 4,241 |
| Niger | 4,200 |
| St Lawrence-Great Lakes | 4,000 |

(Source: *Encyclopedia Britannica Macropedia*, volume 26, 1993.)

## *Waterways Make for a Buoyant Economy*

Today's technology allows people to transport goods using many of Earth's systems. For example, grain shipped from the Midwest may be driven by truck to a silo in Mississippi. The grain might then be floated by barge to a mill and bakery, where it would be turned into bread. The bread would be shipped by truck to your local supermarket. Extra grain might be sold and shipped overseas. Watching from shore, your students may observe lone



ships sailing across the horizon. Help them see more: that lone ship is part of a complex transportation system.

People have been moving goods on waterways for a long time. It is often cheaper to float boats on a river than to build a roadway system and maintain a fleet of ground vehicles. It's no surprise that nearly all the world's great cities developed along water routes. Waterways connect the economies and lives of people all over the world (Data Box 1).

The total length of navigable waterways in the world exceeds 500,000 km. Roughly 10 percent of these waterways are located within the United States. The scale of international shipping across these water highways sometimes is hard to comprehend. The basic point is simple: unless a product in your local store originated within the country, Mexico, or Canada, it almost certainly traveled over water highways. We also depend on shipping to export materials and goods produced in this country. For current data on port activity, imports, and exports check an annual almanac or encyclopedia. Without international shipping, we'd be cut off from many things we take for granted. Be sure to impress upon students the extent to which ours is a global economy.

## *Is Shipping by Boat the Right Choice?*

To move many materials and goods internationally, shipping is the most economical option. Waterways provide an important—and relatively inexpensive—means for moving things within our own country. In choosing between different transportation options, shippers consider three factors: what they want to move, where it needs to go, and how fast it needs to arrive. Surprisingly, most places are within reach of ship and barge traffic. Most easily-found maps now emphasize roads and highways over rivers and waterways; check with organizations in the Resources section for more maps that feature waterways.

The second factor concerns speed of delivery. Planes, trucks, and trains travel more quickly than most barge and ship traffic. Perishables and first class mail make poor candidates for ship's cargoes within the U.S. unless special preparations are made. In contrast, cargoes such as gravel

**Principal Types of Commercial Ships**

| Type of Ship | Percentage |
|---|---|
| Oil Tankers | 31% |
| Ore and Bulk Carriers | 26% |
| General Cargo | 11% |
| Container Ships | 6% |
| Combination Tankers | 4% |
| Liquified Natural Gas Carriers | 3% |
| Oil/Chemical Tankers | 2% |
| Chemical Tankers | <1% |
| Other | 16% |

(Source: *Encyclopedia Britannica Book of the Year*, 1993.)

**Data Box 2**

and scrap metal rarely need to be rushed anywhere. They are therefore ideal for barge traffic. Data Box 2 lists the main types of ships in the world's commercial fleet.

Third, boats and barges are best suited for carrying heavy cargoes that are moved in bulk. As shown on the reverse of the "Navigation" poster, barges typically can carry 500 times the weight and 50 times the volume of a tractor trailer (and about 15 times the weight and volume of a railroad car). Imagine how many tractor trailers we would need to move a load of four barges of coal mined from the West Virginia side of the Ohio River to a power plant near Baton Rouge, Louisiana. The carrying capacity of our inland waterways is tremendous.

## *Navigable Waterways Don't Just Happen*

Maintaining inland waterways is no simple job. Government agencies monitor, maintain, and regulate their use. For example, the U.S. Customs Service oversees imports and exports. Some incoming items are taxed; others are restricted, regulated, or prohibited. The U.S. Coast Guard oversees boating safety, coming to the rescue during disasters and working to prevent accidents through inspection and training. The U.S. Army Corps of Engineers is one of the agencies most involved in maintaining inland waterways. The Corps maintains local offices in every region of the country. It has traditionally had responsibility for large-scale civilian engineering projects, including flood control, coastline engineering, dredging and canal building, and dam and lock construction and operation.

Locks and canals are found on managed waterways. Locks are installed along rivers where dams, falls, shallow water, or other obstructions prevent continuous boat traffic. A shallow river can be converted into a navigable river by building a dam to block the flow of water, thereby raising river levels up stream. Where this is done, a lock must also be built so boats and barges can be raised to the new water level up stream, or lowered to the water level down stream.

Canals are dug to connect one body of water to another. Large ones can cut across countries and join oceans. Some of the greatest engineering projects in modern times have been canals: Erie (580 km long), Suez (184 km), and Panama (82 km). These canals were built as shortcuts, sharply reducing hazards and travel times for shipping traffic. Another reason for building a canal is to reach locations otherwise not available to boat traffic. The Chesapeake and Ohio canal in Maryland is a classic example, built so barges could move along the unnavigable section of the Potomac River. Throughout these many networks, our inland waterways are carefully-managed water highways.

## *The Natural Water Highway*

Water carries more than people and goods. It carries plant and animal remains. If gently deposited and covered by silt or sand, these remains may eventually become fossils. Today, we use coal formed by this process for many purposes, including heat. As they flow, waterways also tend to pick up parts of the lithosphere—bits of clay and sometimes good-sized rocks. When water flow slows or stops, water drops its load in streams, lakes, and on the continental shelves of the world's oceans.

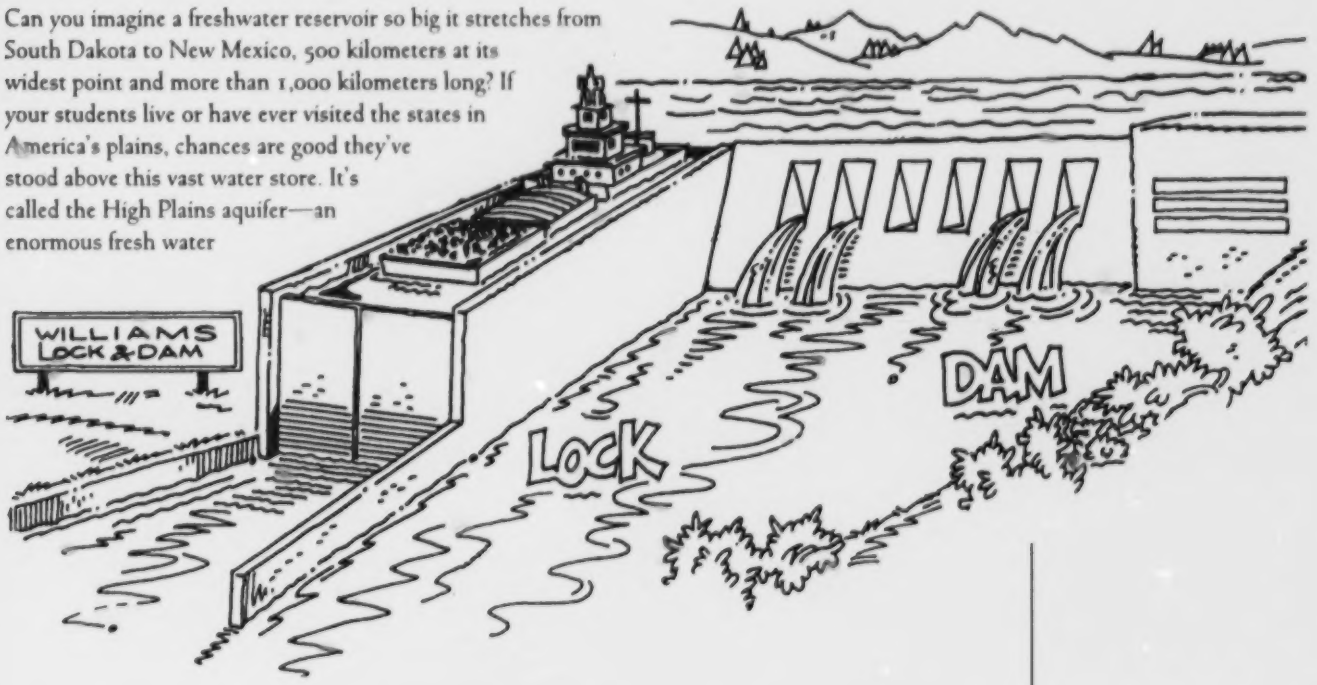
Ocean currents sort the broken lithosphere by size, and put it to rest in deep piles. Over time, water action has transformed Earth's surface. The Grand Canyon, carved by the Colorado River, is a dramatic example of how the lithosphere interacts with the hydrosphere. Can your students describe a more local feature whose creation may have been assisted by the movement of water? Earth's systems continually evolve, change, and interact!

# Ground Water: The Hidden Resource

Your students may be familiar with lakes and reservoirs near your school. But the fresh water stored in places like these is only a small fraction of the water found underground. Roughly 85 percent of all fresh water in the United States lies, literally, *in* the United States. In other words, it's found in ground water. Students usually learn that water cycles include precipitation, evaporation, surface runoff, and the flow of rivers into oceans. This misses what goes on under Earth's surface. (Use the right-hand side of the "Ground Water" poster for comparison.) Nature stores a lot of water underground. The lithosphere is filled with cracks and empty spaces in which water tends to collect. When teaching about the water cycle, don't forget the part that flows under our feet: ground water.

## *A Reservoir That's Not a Lake*

Can you imagine a freshwater reservoir so big it stretches from South Dakota to New Mexico, 500 kilometers at its widest point and more than 1,000 kilometers long? If your students live or have ever visited the states in America's plains, chances are good they've stood above this vast water store. It's called the High Plains aquifer—an enormous fresh water

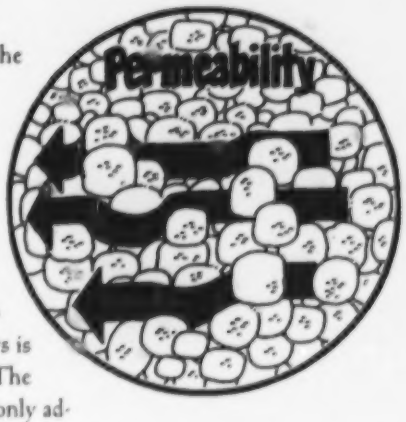



reservoir located underneath Nebraska and parts of South Dakota, Colorado, Oklahoma, Texas, Kansas, Wyoming, and New Mexico. With a holding capacity of nearly four million trillion liters (4 followed by 15 zeros!), the High Plains aquifer serves as the source of fresh water for cities, farms, and ranches throughout this region. Much of our country's corn and wheat crop grows using water from the High Plains aquifer. It provides fresh water for roughly 25 percent of North American farmland, and it feeds and quenches the thirst of about half the country's cattle.

Aquifers are peculiar places. At first, your students might think of them as giant lakes and rivers underground or as huge storage tanks within the rocks. This is not the case. Instead, aquifers are layers of *permeable* rock that are either saturated or partially saturated with water. Permeable materials are those with pores or openings that permit liquids or gases to pass through. Water can move faster through sandy materials than through clay materials.

Drill a well into an aquifer and ground water stored between the rock grains and inside cracks will seep into the hole and be ready for pumping out. For practical reasons, ground water experts reserve the label "aquifer" for areas within rock layers large enough to provide useable amounts of

water. Aquifers vary in type, depending on their particular geological setting; the lithosphere plays an essential role in the type of aquifer that forms.




Ground water occurs in the saturated area of aquifers under two conditions. One type of aquifer occurs when water completely fills an aquifer which is overlain by an impermeable rock bed. (Think of the impermeable layer as enclosing the aquifier.) Such aquifers are called *confined* or *artesian aquifers*. The second type of aquifer is only partially filled with water. As water moves through the aquifer, the top of the saturated area rises and falls. The water in these aquifers is unconfined, and so the aquifer is called an *unconfined aquifer*. The remainder of the ground water discussion in this publication only addresses water in unconfined aquifers.

How deep can an aquifer be? It depends on the permeability of the surrounding rocks. Even impermeable rock sometimes has cracks and empty spaces in which water collects. Gravity forces underground water to filter downwards through rocks until it encounters an impermeable layer. Depending on the permeability of the surrounding materials, water might then flow outward or start stacking up. When the water stacks up, an aquifer begins to form.

## *Charge It!*

Precipitation from the atmosphere recharges aquifers. Rain, snow, and hail may seem to disappear when they soak or melt into the soil, but in fact they are becoming ground water.

In *saturated* material, all the pore space between rock grains and rock surfaces is filled with water. Think about a bucket of tightly packed, fully soaked sand. In unsaturated sand, the pore space is filled with a mixture of water and air. Unless the sand is thoroughly soaked and flooded, water entering the bucket first encounters an unsaturated zone. This unsaturated zone will be present from the surface down to the level where the saturated zone begins. The depth where the unsaturated zone ends and the saturated zone begins marks the water table (Figure 2). The water table rises and falls depending on the volume of water in the saturated zone.

Water may be discharged from under the ground back to the surface. Hills and valleys, road cuts and tunnels, channels and slopes are examples of uneven surface terrain. In some of these terrains, the water table occasionally rises to or above the surface. When this happens, ground water can flow from the aquifer onto the local ground. Places where this happens are *ground water discharge areas*. If you've ever walked along a steep trail and seen water flowing out of the ground seemingly from nowhere, you've observed ground water discharge.

The volume of water flowing from the ground depends on the permeability of the rock, the elevation of the water table, and other factors. If discharge comes through a fissure in otherwise impermeable rock, you might see the distinct start of a stream. (If that fissure opens high on a sheer rock face, you'll see a waterfall!) More common is discharge through permeable rocks over a wide surface area. Wetlands, springs, and ponds are common results. Likewise, the flow of most streams is partially sustained by ground water seeping to the surface.

Ground water is also discharged through wells. Wells are human constructions, produced by drilling a hole to a depth below the water table. Wells supply water so long as the water table remains above

**Aquifers Are Not Sponges**

You might be tempted to tell students aquifers are like sponges. Be careful with this analogy, as it is misleading. Aquifers are found in permeable rocks. Water can pass from one part to another part of the rock through spaces between the grains. Some rocks are more permeable than others, depending on the amount of space between grains. Sponges are different; they are porous, not permeable. In an ordinary foam sponge, water doesn't pass through from one end to the other; instead, it is caught up in the cavities and pores of the sponge—the bubble-like spaces—where it sits until someone squeezes the water out.

the bottom of the well. They "run dry" when the water table drops below that depth. As this happens, wells can be drilled deeper, or they can be closed until the local aquifer is *recharged*. Like discharging, recharging ground water is part of nature's water cycle. Adding water to ground water systems recharges them. How fast an aquifer recharges depends on the permeability of materials in the saturated and the unsaturated zone.

The type of aquifer also has a lot to do with the rate at which it can be recharged. Confined aquifers, like the High Plains, recharge slowly because they are enclosed by an impermeable layer. Of course, recharge rates also depend on the volume of water entering the ground. Recharge is slow in times of drought and faster when precipitation is plentiful.

Sometimes it's hard to distinguish between recharging and discharging. Surface and ground water systems are interconnected. Consider a lake in an area where the water table is high. Water from the aquifer and water from the lake can freely interchange, making recharge and discharge hard to separate. This interconnection is crucial for both surface and ground water systems.

## *A Crucial Balancing Act*

Without human influence, the rate of aquifer recharge would equal the rate of discharge. Yet people depend heavily on aquifers for their fresh water supply. Roughly 40 percent of our country's water supply comes from ground water. Most (about two-thirds) is used in agriculture. This amounts to about three hundred quadrillion (that's 3 followed by 14 zeros) liters of water every day! (Data on ground water use is provided on the reverse of the middle-level "Ground Water" poster.) To maintain a balanced system, we should see nature adding three hundred quadrillion liters of water back into the ground water supply each day. Yet recharge on the global level occurs at a rate nowhere close to the rate of discharge. The result? Just as with banking accounts, if we withdraw more than we replace, one day our aquifers will be empty.

**Figure 2**

Data Box 3 provides a balance sheet for the massive High Plains aquifer. Notice the enormous difference between discharge and recharge—for every one liter recharged into the aquifer, 200 liters are discharged! Ground water experts predict from this tremendous imbalance that if present rates continue, the High Plains aquifer will be unusable over much of its range within 10–40 years. As a nation, we need to better balance our ground water accounts.

## *Ground Water Carries A Legacy*

Water seeping through the ground carries with it everything it has dissolved on its trip through the atmosphere and across the lithosphere. Water combines with carbon dioxide in the atmosphere to form carbonic acid. Although mild, carbonic acid is strong enough to dissolve limestone. When acidic water falls as precipitation it soaks into the soil and enters ground water systems as does regular water. Over thousands of years, this acidic water can dissolve whole layers of underground limestone. Some of this dissolved limestone is redeposited on the surface of stalactites and stalagmites on the ceilings and floors of caves. The process occurs one drop at a time, but in the long run, the results can be extraordinary.

Many kinds of manufacturing processes release chemicals into the atmosphere, where they combine with water in clouds to form acidic solutions. The result is *acid rain*. In cities, acid rain damages statues, building facades, and even paint on cars. When it falls in natural habitats, it damages trees, changes the acidity of lakes, and endangers ecological webs. Over both routes, acid rain affects—usually in negative ways—the quality of ground water.

**Balance Sheet Estimates for the High Plains Aquifer**

| | Scientific notation | Common notation |
|---|---|---|
| **Dimensions** | | |
| maximum width | $5 \times 10^2$ km | 500 km wide |
| maximum length | $1.2 \times 10^3$ km | 1150 km long |
| **Capacity** | | |
| Total capacity | $3.9 \times 10^{15}$ L | 3.9 million trillion liters |
| Typical annual discharge | $2.7 \times 10^{13}$ L | 27 thousand trillion liters |
| Typical annual recharge | $1.3 \times 10^{11}$ L | 13 trillion liters |
| **Discharge to Recharge ratio** | 200 to 1 | |

(Source: William Ashworth (ed.), *The Encyclopedia of Environmental Sciences*. New York: Facts on File, 1991.)

Water also may carry fertilizers, pesticides, and any other water-soluble chemicals we put on the ground. Some of these chemicals have molecules that do not break down in the environment. When they soak into the ground with water, these long-lasting and hazardous chemicals can move into aquifers and into the water supplies for millions of people. This type of contamination can be caused by manufacturers and large farms. It also can begin in your own back yard. What we put or spill on the ground can soak in and just might reappear in our tap water. Earth's systems are so interwoven that contamination in one system may spread to others.

**Data Box 3**

# Water Quality... Potential Sources of Pollution

Chemists say a liter of real water, pure $H_2O$, is impossible to find in nature. Such a large number of substances dissolve in water or are carried in suspension that completely removing all contamination is tricky business. Think about our oceans and the salts dissolved in them; that water is not pure. Or, think of the dirt and debris eroded from stream banks during heavy rains; water carrying that material is not pure either. Knowing this, students are right to ask: "How can I tell if my water is clean?"

## *A Difference Between "Clean" and "Pure"*

People who measure water quality don't run around searching for pure water in nature or spend their time identifying every foreign substance in the water they analyze. Rather, they're concerned about scope and degree. What kinds of unusual or dangerous contaminants are found in the water? How much of each is present? What is the risk of allowing that level of contamination? To them, clean water need not be pure; it simply must be safe. Water is labeled *polluted* when it contains enough contaminanation to pose a risk to health and safety.

Notice that "polluted" is a relative term in water quality. For drinking, water must meet high standards—only extremely low contaminant concentrations are acceptable. In contrast, water used to cool industrial equipment can be much less pure. The same water can be too polluted for drinking but be perfectly acceptable for other uses.

## *Chemical Contaminants Have Many Sources*

Many factors affect water quality. Most people focus first on chemical factors. Because of its physical properties, water readily dissolves many substances: from minerals and salts in rocks to sugar and food coloring in drinks. Substances that do not dissolve easily in water (oils and gasoline, for example) either float on the surface, sink to the bottom, or are carried along in broken-up globules. Accidental spills cause some chemicals to enter our environment. Car owners and mechanics, for instance, might

accidentally spill gasoline onto the ground at a filling station. More often, introduction happens through careless handling, poor judgment, or sloppy disposal. Without thinking of the consequences, many people pour polluting chemicals down their sinks and drains: from pesticides to paint remover. Overfill a lawn mower and the spilled gas seeps into the ground. Wash a car or bike on a lawn, and the soaps and grime that fall into the grass enter the soil as well as the water cycle.

Tracking chemical contamination of water supplies is complicated by the wide range of chemical compounds. Different chemicals pose different kinds of threats. One growing concern is the overuse of pesticides, herbicides, and fertilizers by people trying to improve their lawns and gardens. Often, the amount of chemicals applied far exceeds what is needed for healthy growth and protection. Plus, consider the chemicals used to maintain a neighborhood's recreational spaces for baseball, football, soccer, and golf. (Encourage students to investigate local examples as well as alternative lawn care methods.)

Insecticides and herbicides target unwanted organisms. But all organisms, including humans, have much in common. Despite the most careful use, sometimes these chemicals affect humans and other non-targeted organisms. Some insecticides and herbicides, for example, cause serious health problems such as cancer and reduced immune responses. Overuse of these chemicals can be devastating for water safety.

Usually composed of nitrates and phosphates, plant fertilizers promote plant growth when applied to lawns, fields, and gardens. But excess fertilizer is carried away in runoff water. The contaminants may then flow into streams and seep into ground water. When they get into nature's water systems, fertilizers promote growth where we don't want it. In lakes where these nitrates and phosphates accumulate, plant and algae populations can balloon to enormous levels. Large populations of microorganisms can cause disease and may foul fresh water. Overgrowing plant populations may crowd out other life forms and clog boating lanes. They also can block sunlight from reaching far below the surface, which may mean disaster for bottom dwelling photosynthesizers. Excessive nitrate levels in drinking water pose a health hazard because they impair the blood's ability to carry oxygen. Infants and young children are especially vulnerable to high nitrate levels in water.

## *Can You Point To A Point Source?*

Some sources of chemical contamination are easy to locate and stop; others are not. The easy ones usually are *point sources*—single, specifically-located outlets of pollution. Common point sources are wastewater treatment plants, storm drains, factories, outlet pipes, and drainage ditches. If a student reports oil floating in a local creek, water-quality experts follow the trail upstream, looking for a broken pipeline or a cracked storage tank. In other words, they look for a *point source*.

Unfortunately, many causes of chemical contamination are not located so easily. *Non-point sources* originate in a broad area and cannot be isolated to any single cause. As a result, non-point pollution is difficult to prevent. High concentrations of fertilizers in lakes, rivers, and ground water offer a good example. Farmers point to suburban lawn care as the source of the problem; suburban homeowners blame farmers. Although water quality experts have a difficult job measuring the relative contributions of these non-point sources, both clearly contribute to the problem and each has a role in its solution.

## *More Causes Than You Suspect*

Solving water quality problems begins with several basic steps: identifying contaminants, determining the safe level for those contaminants, and identifying their sources. Once these steps are taken, we can make plans to reduce the levels of contaminants in the water system.

Students probably think of water quality problems largely in terms of chemical contaminants, and they will think of water use largely in terms of drinking water. As you expand their understanding of water uses, also encourage broader concepts of water quality. Data Box 4 lists eight classes of water pollutants. One useful technique for expanding appreciation of the range of water pollutants is to work by example. Ask students to imagine a family on a fishing and photography trip along one of the streams in the "Water Quality" poster. In addition to chemical contaminants in the water, what else might affect either the water quality or the quality of their experience along the trip? As they will see, problems in the water system can have a huge impact on other Earth systems.

**Data Box 4**

**Eight Classes of Water Pollutants**

Oxygen-demanding Wastes
- Removes dissolved oxygen

Plant Nutrients
- Especially nitrates and phosphorous

Organic Chemicals
- Especially pesticides, herbicides, and detergents

Other Minerals and Chemicals
- Petrochemicals, salts, acids, and industrial wastes

Sediments from Land Erosion
- Run-off from farms, construction sites, and land without vegetation

Infectious Agents
- Bacteria, viruses, and protozoa

Radioactive Substances

Heat

Physical changes in river water have important effects on water quality. *Thermal pollution* occurs when water from one source significantly alters the temperature of a second water source. For example, a manufacturing plant may distill all the contaminants from its wastewater before releasing it into a nearby river. But if the wastewater is much warmer or colder than the river water, the temperature can affect plants and animals in the river.

Most aquatic organisms can survive only in a narrow range of water temperatures. Fish can suffocate in overly warm water because warm water holds less dissolved oxygen than cool water. Temperature changes alter key physiological processes, just as people function differently in hot and cold environments. When temperatures change beyond preferred ranges, organisms may relocate or die. Those that live may be unable to reproduce or function normally.

In overly warm waters, the metabolism of many microorganisms speeds up dramatically. Populations can swell to a point where they drain limited supplies of nutrients, cloud the water, and crowd out other organisms. When this happens, an observer may notice large films of algae in the water, or have trouble catching fish. In fact, a change in water temperature can cause an entire ecosystem to collapse.

Another way to measure water quality is its relative acidity, or pH. As with temperature, slight changes in relative acidity can be harmful or fatal for many organisms. When acid rain falls into a watershed, it increases the acidity of the water used by plants and animals. If those organisms cannot tolerate the changes, they either migrate or die. As with changes in water temperature, changes in water acidity can also lead to ecosystem collapse. Although both developed and developing countries are developing strict legislation to curb this problem, acid rain continues to impact all Earth systems.

Commercial processes such as construction, strip mining, and clear-cut logging also affect

water quality. Because they strip the ground of vegetation and leave large surface areas exposed to rain and wind, these activities increase the rate of erosion. Without roots to hold it in place, eroded soil can clog streams, smother organisms, and cloud rivers. Soil in rivers may block sunlight, thereby preventing photosynthesis in water plants. A family hoping to fish and nature-watch might have a hard time succeeding downstream from these kinds of operations if proper pollution control measures are not taken.

# How Can People Protect Water?

You may want to take some time to have students reflect on what they have learned from this volume of *Water Matters*. There are many ways students can learn to use water wisely. The first step is to reduce the amount of water we use. Data Box 5 shows a handful of simple steps that everyone can take to accomplish this important goal. Next, think about ways to safeguard the quality of our water.

Have students generate a list of ways they and their families can reduce the amount of contaminants in the water supply. Your students may be surprised to learn that an average household generates nine kilograms of hazardous waste annually. Have your students do an inventory of household cleaning chemicals. Did they know that they can substitute baking soda for abrasive scouring powders and hot water for drain cleaners? Many people do not properly use fertilizers and pesticides, resulting in unnecessary pollution. Have the students make sure their families are using fertilizers and pesticides that are of the right type for the soil. They must use and store such chemicals in strict compliance with directions on the packages.

Your students might want to research the practices of the school district or local community. Does your school or local government use hazardous materials? Are there viable alternatives that are less polluting? When going through these activities, always stress the need for students to carefully consider tradeoffs. Alternatives may be less polluting but more expensive, or require increased use.

If you have time, your class could develop a campaign to alert its school (or the community at large) on methods to reduce water pollution. Can students undertake a public relations campaign urging people to save water? To use less hazardous household chemicals?

Many state or federally-owned park preserves sponsor nature appreciation programs; trail, pond, or lake cleanup days; and water education seminars. Find out more about upcoming water-related events at your local park systems, and get your students involved.

Many communities have cleanup days where residents can bring hazardous materials. If your community sponsors such an event, what can students do to increase participation? If not, can the students petition the government to sponsor one? Every solution, no matter how small, helps preserve Earth's systems.

**Data Box 5**

**Simple Ways to Save Water**

| Action | Liters of water saved |
|---|---|
| Check for leaky toilets and dripping faucets | 380 per day |
| Install water-saving showerheads and faucets | 23–38 per minute |
| Don't let water run while brushing teeth | 95 per minute |
| Don't use the toilet as a wastebasket | 23 per flush |
| Take shorter showers | 210 every 10 minutes |

(Source: America's Clean Water Foundation, "Clean Water is Everyone's Job," Washington, DC, 1990.)

# Activities for Students

This section presents activities growing from the three Water Resources posters bundled with this volume of *Water Matters*. These are hands-on, interactive activities, with special attention paid to cooperative learning, interdisciplinary studies, and science literacy. Activities are keyed to particular posters, and several sequences—where one activity builds on a previous one—are included for larger lesson blocks. Additional curriculum materials, water resource organizations, and reference guides are identified in the Resources section found on pages 29–30.

**Why Two Copies of Each Poster?**

This package contains *both* versions of each poster. Although the fronts are identical, the backs are not. One version has background and ready-to-use activities for grades 3-5; the other, grades 6-8. Having two posters allows you to display the front of one while cutting the other into sections for use in various activities. Laminating both the whole poster and the pieces of the other will increase longevity; for your own future reference, make several copies of each panel on the posters before lamination and store a master copy.

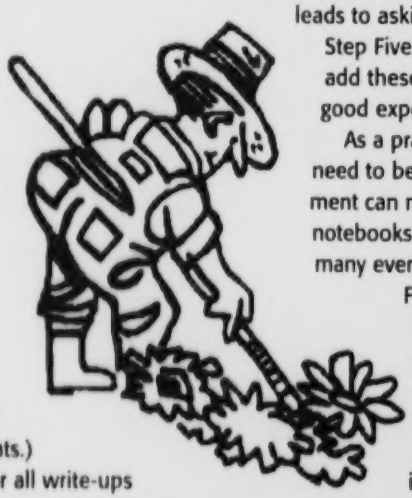
## *Keeping a Water Journal*

There are as many ways to keep a journal as there are interpretations of the word. Journals for class work need to serve several purposes. First, they must meet student needs. A journal is a place to keep notes, graphs, maps, records, reflections, and any other information useful for understanding a topic. Because journals grow and expand, students need ways to add new information. Loose-leaf binders—or sections of one—offer the most flexibility for growing journals.

Second, well-kept journals teach much-needed principles of organization. Pages must be numbered and kept in order. Leave room at the front for a table of contents. Be sure students' tables of contents reflect new entries. As an aid, you might post your own expanding contents list for comparison. (This also will help students who have been absent and need to make up assignments.)

Choosing a uniform format for all write-ups may be too restrictive an approach, because not all activities will be experiments, per se. Plus, too strict a reliance on format may dampen creativity. Nevertheless, encourage careful record keeping at every step. The reason is simple: repeatability. Accurate logs of what researchers were doing, how they were doing it, why they did it, and what they found are crucial for continuing investigations. Good record keeping means a student can return to an experiment weeks, even months, later and not have to rely on memory to recall what took place. It also means someone else can read the journal and understand exactly how to repeat the activity and what to expect. A good rule of thumb for record keeping (no matter what format is adopted) is to use the "make up" standard. Have students keep records so their logs could be used by students who were absent and need to make up the activity. If they require no further instruction, the record keeping is fantastic!

For each activity, you'll generally want students to record information along a number of basic lines. Each of the following activities poses a question. You might use this as Step One. Ask students to rephrase the question or suggest why this question is worth asking. Step Two might include describing the material and methods used while investigating the question. Step Three could provide records of observations, data collected, and notes on anything peculiar. Always insist data collected be related back to the original questions. This can be done in Step Four. Finally, research sometimes produces unexpected results and always leads to asking new questions. Add a Step Five in which students can add these additional thoughts. One good experiment leads to another!



As a practical note, journals also need to be teacher-friendly. Assessment can mean hauling boxes of notebooks home and spending many evening hours grading. Fortunately, there is an easier way: periodically give an open journal quiz. Ask questions about material found on specific pages. For instance, "Locate experi-

ment three in your journal and tell me two observations you made during that activity." If you don't tell them which activity that was, students will be forced to rely on their notebooks—and not their memory—for the answer. This method assesses record keeping as well as the actual investigation. Tell students to expect such quizzes when you begin your water curriculum; this provides a powerful incentive for keeping records up-to-date and in order. Also build time into your activities for journal maintenance. When you have completed your water curriculum, have students create a finished product by stapling all related papers together, with a cover. A body of knowledge begins.

Another useful technique for simplifying assessment involves parents. Be sure they are aware their children are keeping journals in science class. Write them a letter describing your plan and expectations, including some of the specific details about the journals. Get a signed receipt from each parent. Ask them to examine their child's notebook once a week. Add places for parent's signatures in the journal entries. Call the parents of each student who scores low on the first journal quiz. As always, parents can be your best ally in establishing good study and work habits.

## *Activity 1: Where Would I Go? What Would I See?*

*This activity introduces the poster, "Navigation: Traveling the Water Highways!" with an opportunity for creative writing. Students then write a short story about a water journey, either real or imaginary. It then asks students to trace the course of an actual waterway in your state and discover basic facts about that water highway. Start your investigations where all travelers start a journey—with a good map.*

The word navigation seems too global and distant to be meaningful to most students. But kids love boats and usually find ways to get on the water. Do you have any Huck Finns in your class who have made a raft? Any water-borne Amelia Earharts who have explored in a canoe? Maybe some of your students are sailors or water skiers. Let kids write a short story about a particular water experience they have had. You can also invite them to write a fictional account of a journey by having them imagine they are the captain of a ship traveling one of your state's water highways. Have them write a short story about who they are, what they do as a captain, and what life on the water is like. Tell them they just got word they need to move their cargo along the waterway to an up-town river. They can describe the journey and the towns they encounter along the way. Whether real or fictional, students' stories can become the first entry in their water journal. You also might have students share part of their stories in small groups.

It's one thing to imagine life on a water highway. Comparing imagination or personal stories with more specific facts offers a useful constructivist experience. This is a wonderful opportunity for your students to learn some state geography and map reading skills. As a second part to this activity, divide students into groups of three or four. Give each group an official, detailed state map. (Depending on where your school is located, local examples may be plentiful. Otherwise, try regional, national, or even international maps. A list of the world's major rivers is provided in Table 1. Your librarian may also help you find suitable maps.) Give students five minutes to look over the map and ask them to generate at least two questions. Let each group ask their own questions, and give classmates the first opportunity to answer them. At this point you might want to pass out rulers and have them figure out the kilometers between two cities. Then use a questioning strategy to teach any other map reading skills you deem important. For example, you may want to ask:

• Does this map have a legend? What is a legend?

• How do we use a legend?
• Does the legend have a scale?
• What do these scale numbers mean and can you use them?

Then, provide each student with a notebook-sized state map showing (but not naming) important rivers, lakes, and/or oceans. Working in groups and using the official state map, each student will write the names of the major state rivers, lakes, and oceans on his/her notebook map. Ask your students to write their names in ink at the top of each page and place them into their water journals.

### *Activity 2: Do Rivers, Lakes and Oceans Have Stories to Tell?*

*Now that your students can locate the navigable waterways on their state map, they can begin gathering historical and scientific information about water highways. In Activity 2, students develop a deeper knowledge of local waterways. The objective is to help students see that geology, geography, and history are part of an ongoing tapestry that weaves a fascinating story.*

Ask students to name all the geological, geographical, and historical things there are to know about a waterway. Let them generate as many questions as possible. Record the science questions on one overhead and the historical questions on a second. Some sample questions are listed below; students will likely think of these and many more questions.

You will want to decide which questions are best for your lesson objectives before making copies for students. If you do give them copies, have them write page numbers at the top right. This makes them responsible for keeping the papers and you will have to make far fewer duplicates for lost papers.

Now it's time for students to begin finding answers to their water highways questions. Divide students into groups of three or four and assign each group a specific waterway. You will need to have maps available for consultation, and students should be told where they might look for information about their assigned waterways (e.g., encyclopedias and the Internet). Don't forget the water resource specialists in your state! Ask one of your students to contact the state geologist or local USGS representative. At some point, invite a state river specialist to share knowledge and stories about one or more of the state's rivers.

As your students answer the list of questions, make sure they number the pages of their responses and place them in their water journals. Be sure the responses also include lists of sources consulted.

You need to set the time line and the writing parameters, but there can be endless variations to this assignment. Each student should be responsible for a written report, whether it is an individual project or part of a group effort. For example, results can be summarized in standard form (e.g., on index cards) and pinned to a wall map for display.

If you have students who enjoy drawing, cover a portion of the wall with butcher block paper and use an overhead projector to shine an outline map of the region studied onto it. Your students can draw the outline for a start, then add information about the waterways to that map as they learn more. You may end up with a classroom treasure!

**Sample Questions for Activity 2**

**Science questions concerning rivers might include:**
- How big is the river's watershed?
- What direction does the river flow?
- Is the flow constant, or quite variable?
- What are the sources of the river's water?

**Historical questions might include:**
- Who first used the river as a water supply or for navigation?
- Is the river currently beng used to transport goods?
- Have people built dams across the river; if so, for what purpose?
- Who manages this waterway?
- Have people living along the river experienced flooding?
- Is the river clean enough for fishing or swimming?
- Who or what is polluting the river?"
- What are the people in the state doing to clean up the river?

| | 1980 | | 1985 | | 1990 | | 1993 | |
|---|---|---|---|---|---|---|---|---|
| **Petroleum products** | 381 | 305 | 332 | 233 | 394 | 253 | 385 | 246 |
| **Crude Oil** | 432 | 157 | 322 | 176 | 437 | 158 | 455 | 132 |
| **Coal** | 230 | 148 | 247 | 162 | 301 | 201 | 263 | 189 |
| **Sand & gravel** | 59 | 55 | 59 | 56 | 57 | 51 | 59 | 50 |
| **Iron & ore** | 88 | 59 | 66 | 45 | 77 | 57 | 74 | 55 |
| **Corn** | 89 | 28 | 68 | 26 | 86 | 36 | 71 | 32 |
| **Wheat** | 48 | 13 | 34 | 10 | 40 | 12 | 48 | 12 |
| **Soybeans** | 33 | 14 | 30 | 14 | 29 | 14 | 34 | 16 |
| **Farm products** | 195 | 57 | 156 | 54 | 194 | 71 | 187 | 68 |
| **Chemical products** | 83 | 44 | 98 | 48 | 112 | 60 | 122 | 64 |
| **Lumber products** | 47 | 21 | 42 | 17 | 52 | 20 | 45 | 18 |
| **Metal products** | 26 | 8 | 30 | 8 | 25 | 7 | 29 | 8 |
| **Waste & scrap** | 28 | 17 | 33 | 22 | 55 | 29 | 49 | 24 |
| **TOTAL** | 1799 | 970 | 1609 | 913 | 1948 | 1010 | 1915 | 961 |

Table 1
Waterborne Commerce of Various Goods

Values in shaded columns are the number of metric tons of each item shipped through ports and along waterways in the United States. Values in unshaded columns are the number of millions of metric tons shipped through ports of the world and along inland waterways. Note: Petroleum products include predominantly gasoline and refined oil. Sand and gravel category includes crushed rock. Lumber category excludes furniture. (Source: *Statistical Abstracts of the United States*, 115th ed. Bureau of the Census: Government Printing Office, Table 1084.)

## *Activity 3: What Moves Over Our Water Highways?*

*This activity introduces data on the movement of materials and goods along our country's water highways. Students are asked to create graphs and charts using this data. They also have the opportunity to ask deeper questions about graph making, visual representation of data, and how to identify trends in data.*

To give students a basic understanding of the quantities of materials shipped along waterways, ask them to examine Table 1. Because this is a complicated data set, take time to teach "table reading" skills.

Ask students to analyze this data set by expressing some part in graphical form. Have them work in teams around single topics. One team, for example, could study farm products. One student in that team could track the change in number of tons of corn carried through American ports and waterways between 1980 and 1993. Another could do the same for world ports. A third and fourth team member could focus on wheat or soybeans. Then the teams could compare their graphs. (This provides an opportunity to talk about scales for graphs and the importance of uniform scales.) What patterns emerge? Are any of these data unexpected? What might be causing these data patterns.

So students can compare their results easily, combine data sets onto a single graph. One approach to this comparison is to post a large poster board on the wall. You make the

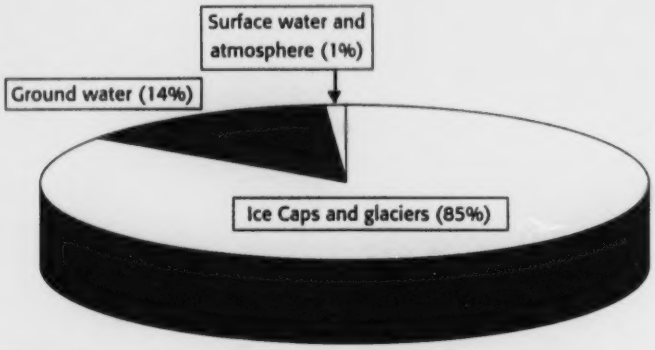



**Figure 2**

Location of Earth's Fresh Water

scale and the axes. Then, ask each team to draw their results on that graph. Alternatively, photocopy a blank, scaled graph onto several transparencies. Give one copy, together with a unique color marker, to each team for their report. These transparencies can be overlaid on an overhead projector. Alternatively, while some teams are studying the volumes of one commodity over time, others could be studying the relative importance of products in one year. Pie charts are useful for this type of comparison.

Encourage students to ask questions about these results, recording those questions in their water journals. Compare the volume of materials moving through our waterways. Compare trends in how those volumes are changing. What kinds of products are the most important? What does that say about American society? Ask students to imagine they are in charge of environmental safety for our country's waterways. What problems would they expect most frequently and be most worried about? What precautions would they take? What cargo creates the largest business for the shipping industry?

## *Activity 4: Can Rocks Really Absorb Water?*

*When starting activities related to the "Ground Water" poster, students frequently wonder how rocks can store water. In this activity, they examine the water-absorbing properties of different kinds of rocks by soaking rock samples in water for several days and measuring changes in mass. This experiment is best run over a weekend.*

Of all the world's fresh water, 85 percent is trapped in ice caps and glaciers. Only a small fraction is available in surface water (seven-tenths of one percent) or in the atmosphere (three-tenths of one percent). The rest (14 percent) is found in ground water. (Source: *Water Matters, Volume 1* poster, "Water: The Resource That Gets Used & Used & Used for Everything!" Note that these figures do not include saline ground water.) Students often find it difficult to visualize how rocks can hold water. This experiment shows them.

Divide your class into small groups. Provide each group with egg-sized samples of at least four different rocks, e.g., sandstone, shale, limestone, and granite. Add others—e.g., lava, obsidian, gneiss, gypsum, etc.—as resources permit. (You might encourage students to bring to class rock samples they find in the area.) To start, do not identify the rock samples. Let students spend time examining the samples. Pass around hand lenses and ask students to record in their water journals descriptions of what they see and feel. Rocks vary widely in color, size and shape of particle, texture, and light-reflecting qualities. Be sure information along such lines is recorded. Also note if samples have cracks, cavities, or fissures. Ask students to discuss and predict (keeping a record in their journals) which sample will hold the most water.

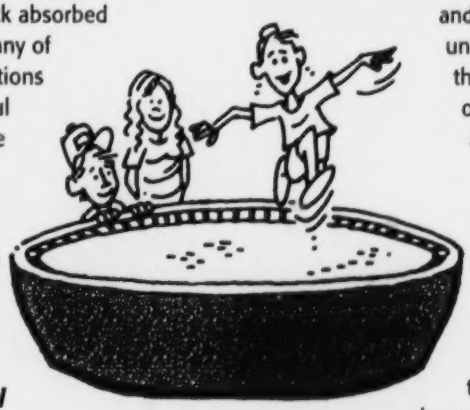
Let each group collect a balance, a strip of masking tape (for labels), and one clear plastic cup for each rock sample. (Standard 9-ounce cups hold approximately 270 ml of water; these are ideal.) Ask the groups to put each rock sample in a separate cup, then label the cup with their group's names and the sample number. If students can guess the names of each rock, have them write those names on the labels, too. In their water journals, students should create a data table for this study with columns for the sample name or number, the sample's mass before soaking, the sample's mass after soaking, and the resulting change.

Once the data tables are made, each team should place weigh their different rock samples in cups. Then have them record the sample's "mass before soaking" in their journals. Be sure each student has an opportunity to use the balance. When the initial measurements are complete, let each group collect a container of

water and instruct them to fill each cup about 3 cm above the top of the sample. Ask them to observe the samples for a few minutes, recording observations in their journals. Let the rocks soak for several days. (In the interim, you may need to cover the cups or add water.)

After the waiting period (keep a record of the length), have students return to their samples. One student should carefully remove each sample from the water, while another drains the cup and dries it with a reusable cloth. Let surface water drip from the sample, then return it to the cup for measurement. Record the sample's "mass after soaking" in the data table, then subtract the "mass before soaking" to discover the mass of water absorbed by the rock.

To help students draw conclusions, ask them to discuss and record in their journals answers to key questions: Which rock absorbed the most water? Why? Are any of the before-soaking observations made for the samples useful in understanding how these rocks absorbed water to different degrees? Which rock sample would be the best for an aquifer? Be sure students don't think rocks are like sponges.



## *Activity 5: Where can I Find a Water Table?*

*In this activity, students use basic tools to build a simplified model of an aquifer. This provides an opportunity to identify movements in the water table as well as to identify saturated and unsaturated zones in the ground.*

Ask this question without definition or explanation and see what sorts of responses you receive: "Where can I find a water table?" Tables usually aren't made from water, and your students might think you're joking.

Give each student two clear plastic cups. Have them fill one cup about two-thirds full with pea-sized gravel; the other, about two-thirds full with water. At their desks, ask them to slowly pour the water into the gravel until the water rises about halfway up the cup. Give students a few minutes to examine this creation.

Your students have created simplified models of an unconfined aquifer. (Aquifers can be rather complex geologically.) The top of the water is the water table. Forgetting the air bubbles for a moment, the gravel beneath the water table has all the spaces between rock grains filled (i.e., saturated) with water, so this is the zone of saturation. Above the water table, students might see some water but air fills most of the space. This is the unsaturated zone.

Ask students to raise the water table to about 2 cm below the surface of the rocks. What happened to the zone of saturation and the water table? Use a finger to "drill" a hole in the gravel. What is it modeling? What are they modeling if they drop the water table below the bottom of their hole?

Give each student a portion of a clear plastic straw. Have them put the straw into the gravel and at least 3 cm or so under the water table. If they put their finger firmly over the top of the straw and pull the straw out, some water should remain in the straw. Ask students what they are now modeling. The straw represents a simple pump. Ask them, "What happens if the water table falls beneath the pump?" If your community depends on ground water, they can now see the importance of the water table. Encourage students to model other water-related activities using this system. Be sure they record these efforts in their water journals.

## *Activity 6: Can We Balance Our Aquifer Accounts?*

*In this activity, students experiment with rates of aquifer recharge and discharge to understand the relationship between the two and the need for responsible rates of water consumption.*

This activity is best done outdoors as a large group exercise (10–12 students), though it easily can be adapted for other situations. Begin by creating a model aquifer and well. Cut the ends off a large, metal coffee can or other wide-diameter tube. Place the can vertically in the

large bucket or tub. This configuration models a well drilled into an aquifer. Fill the surrounding area of the tub with pea-sized gravel.

Begin with a fully charged aquifer by pouring enough water into the tub to raise the water table to near the top of the gravel. Another bucket of water should be nearby, 10–15 paces from the well. Take this opportunity to discuss the key concepts of this model: saturation, water table, discharge, and recharge.

Distribute cups of varying sizes to members of the group. Designate some in the group as "rainmakers" and others as "water users." (For fun, you might distribute cards for these assignments: "thunderstorm" for a rainmaker with a large cup, "drizzle" for one with a small cup, "single-family home" for a user with a small cup, "irrigation farmer" for a user with a large cup.)

Use a ruler to measure the height of the water table in the well. To do this, measure the depth from the top of the well down to the height of the water table. This results in a reverse measurement (*e.g.*, five inches is less water than three inches.) Then, run a cycle of discharge and recharge. Dischargers fill their cup with water from the well and place the water in the nearby bucket. Rechargers draw a full cup of water from the bucket and add it to the gravel.

Use whatever sequence of these twin processes as you wish, measuring the height of the water table at regular intervals. Try various combinations of discharge and recharge through the ground water system. For example, you might run a drought for a few cycles (no recharge, but continued discharge). Or, grow the population of users to represent an expanding community. Or change the volume of one user's cup in a dramatic way–*e.g.*, from 100 ml discharge to 1,000 ml discharge–to represent a change in a manufacturing process.

All along, draw students' attention to the height of the water table. As the table lowers, ask some of the users what they might do, speaking for their role, to assist in conserving the water supply. Help them understand that there is no "magic source" for more water; the water cycle is a closed system. How can they keep discharge and recharge balanced? If the aquifer runs dry, who loses?

## *Activity 7: What does Porosity Have To Do With Ground Water?*

*There are many kinds of earth materials beneath the soil. Some are porous, others are impervious to water. Pores are very small openings or empty spaces, so porosity is the term used to describe the water-holding capacity of earth materials. In this activity, you can reuse the pea gravel from Activity 6. Students will explore the porosity and runoff of various earth materials.*

Create a mixture of pea gravel and dry sand, using equal amounts of each. Then divide students into small groups. If manageable, two students per groups will give them the most hands-on experience. Each group will need two clear plastic cups, a 100 ml graduated cylinder, water, and enough pea gravel to fill one cup and enough pea gravel-sand mixture to fill another. With the two filled cups in front of them, ask each group to predict which will hold the most water and why they think this is so. Looking at their graduated cylinder, ask them to estimate how much water each cup should hold. Students should write these predictions on a new journal page, titled and numbered.

If your students have never used a graduated cylinder, you will need to discuss the calibration and demonstrate how to read it. Have each student practice reading the graduated cylinder. Then, have them measure the total volume of the cups they are using (cups that hold 270 ml work well) and record that volume in their journals.

Ask each group to pour the water into their graduated cylinder to the 100 ml mark. Then, slowly fill the pea gravel cup with water. It is important to pour carefully so the water does not splash or overflow the cup. Have students read the graduated cylinder to determine how much water is left. To determine how much water the cup aquifer held, subtract this amount from the original 100 ml. Refill the graduated cylinder to the 100 ml mark, and repeat the procedure with the pea gravel-sand mixture. Have students record these numbers in their journals.

Now have students find the percent porosity of the earth materials in the two cups. Ask each groups to discuss what they will do with the

numbers they have found to calculate the percent porosity. Hopefully, at least one student in each group will suggest dividing the volume of water poured into the cup by the total volume of the cup. Have them do the calculations for each cup, and record the porosity of the gravel and the gravel-sand mixture in their journal.

Have the class as a whole discuss their results. Why did the pea gravel hold more water than the pea gravel-sand mixture? Most students will notice the sand filled the spaces between the gravel particles, leaving less total pore space for water.

Ask students to pour out the water remaining in their graduated cylinder. As carefully as possible, have them pour the water from the gravel cup into the empty cup, then measure this water in the graduated cylinder. This volume should be recorded in students' journals. Repeat this procedure for the gravel-sand cup. For each cup, compare how much water was poured off with how much water was used to cover the earth materials. Why are these figures different? At this point, you may wish to introduce such concepts as adhesion, cohesion, and surface tension. Which of the two cups of earth materials returned more of the water, and why?

### *Activity 8: How Permeable is the Soil Around Here?*

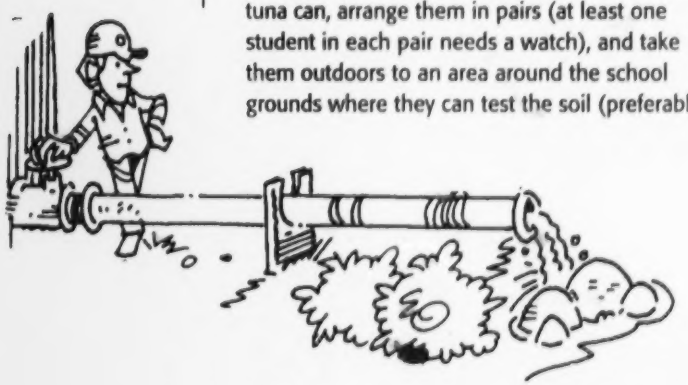
*In this activity students examine the principle of permeability in soil materials. First, this is done through demonstration; second, through experiments in the school yard. This activity requires two class periods and some unusual materials.*

There are no rivers underground. Instead, water moves through spaces between rock grains. The rate at which this movement occurs depends on how permeable the rock is: more water can flow through a highly permeable material in a given time than can through a less permeable one. Students explore permeability of local soils in this activity. In preparation, collect as many empty tuna fish cans as possible. (Larger cans, such as juice or soup cans, will work, but may be harder to work into the ground.) You will need one can for each student in class. Ask for volunteers to bring them into class. Use a can opener to remove both top and bottom, being careful not to leave any burrs or sharp edges.

For the first day of this activity, assemble a demonstration table containing clear plastic cups packed separately (two-thirds filled) with sand, gravel, potting soil, and clay. Have several holes punched in the bottom of these cups and suspend them on cake cooling racks above bowls into which water can drip. Introduce the concept of permeability, then ask students to predict which among the samples will be most and least permeable. Allow time for recording observations in their water journals. Have samples available of each material, plus hand lenses, for examination. Be sure students record the reasoning behind their predictions.

To demonstrate permeability, ask four volunteers to be ready with cups of water, four volunteers to time events (use one clock for everyone), and four volunteers to record the times. At the go signal, have the water handlers each pour their cup of water into their assigned sample. As soon as they begin, the clock starts. Each watcher calls time when water starts dripping into the bowl below. When all times are recorded, discuss the results and compare the predictions. What has just happened?

Students love outdoor activities. For the second part of this activity, give each student one tuna can, arrange them in pairs (at least one student in each pair needs a watch), and take them outdoors to an area around the school grounds where they can test the soil (preferably



bare soil; as a last resort, a sand pit). You need to bring along a 100-ml graduated cylinder, and enough plastic cups filled with water so each team can have one cup. You may wish to bring a bucket of water in case you need more.

Once in your experimental field, show students what you want them to do. Firmly turn and push the tuna can into the soil until about half the can is underground. This is your permeability test site. Note special features of the site: Is the soil packed or loose? Is it already wet or is it dry? Is it sandy soil? Does it have a lot of decaying plant material?

Measure 100 ml of water. Have the timers ready with their watches. At the go signal, quickly but carefully pour the water into the remaining part of the can. Call stop when all the water passes into the soil. Record the time. This demonstrated, have each student perform this procedure around your experimental site, recording their results. It might be wise to have students repeat the procedure at a new spot close to the first. When finished, remove a small soil sample of each area intact for study back in class. If students are testing soils that look different in quality, be sure they note this, as their results may have good reason to vary! Once back in the classroom compare results and again discuss soil permeability. What can your students say about the local soil permeability? Be sure reports and conclusions are included in their water journals.

Many variables can affect the results in this activity, especially if soil is packed differently over the experimental site. Soil type is likely to be the same, though you might locate different types of soil so results will vary for good reason. This activity also provides an ideal opportunity to discuss experimental variation and the importance of using controls in experimental procedures.

### *Activity 9: What's So Hard About Water?*

*This activity introduces experiments for the "Water Quality" poster with a focus on water hardness. Water hardness is easily tested by measuring the capacity of water to make soap lather. Students compare the hardness of waters from a wide range of sources.*

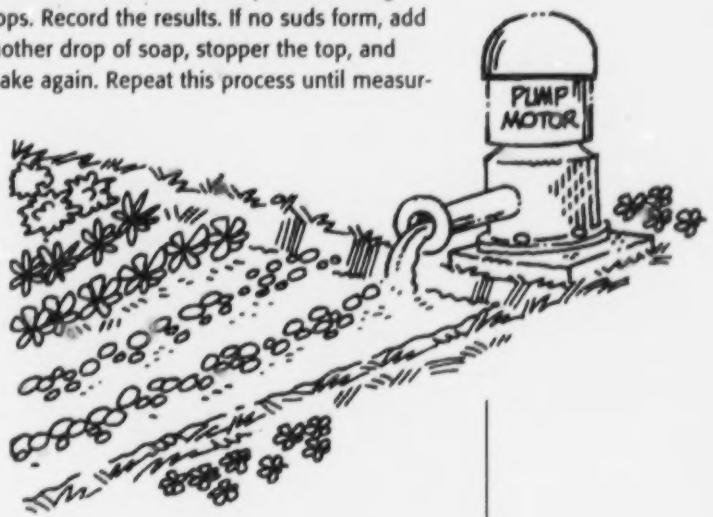
Anyone who has every "belly-flopped" off a diving board knows water's surface can feel as hard as wood. This is one concept of water "hardness." Water quality experts use "hardness" in a different sense. It relates to the kind of salts and minerals dissolved in a water sample. As water passes through soil and deeper Earth materials, it can dissolve minerals such as iron, calcium, and magnesium if they are present. When water containing these materials is pumped out of the ground and used in homes, the minerals react with soap and prevent lathering. Such water is called "hard" because

over time the minerals precipitate out and form hard deposits in plumbing fixtures. The relative hardness of water is measured by the amount of $CaCO_2$ present. Water "softeners" work by replacing calcium with sodium. In this activity, students compare the relative "hardness" of water from different sources.

Use a plastic soda pop or milk container to prepare a two-liter sample of hard water. To do this, dissolve 250–300 ml of Epsom salt, which contains magnesium, in warm tap water. Fill a second container with water that has been passed through a water softener and a third with tap water from school. Also purchase a two-liter sample of distilled water. If resources allow, use additional samples as well: rain water, spring water, commercially bottled water, sea water, pond water, water from a student's home, etc. Label the sample bottles with numbers and be sure everyone writes the key to these numbers into their water journals. Rinse a number of 10-ml graduated cylinders with distilled water. Then place the samples and the graduated cylinders at stations throughout the room, to prevent mixing samples during the experiment.

Arrange the students into groups. Each group will need a test tube rack with enough tubes and stoppers for the number of samples they will test. A good rule of thumb is for one person to perform one test. Label the test tubes according to sample assignments. Using the graduated cylinders, have students measure 10 ml of their particular water sample into the appropriate test tube. Be sure not to use the same graduated cylinder for more than one kind of water sample. When the groups reassemble, provide each group with a small jar filled with liquid soap, and an eye dropper. (For the soap, a low foaming agent liquid soap is best. Do not use liquid detergents, which were developed to lather in both soft and hard water.) Be sure the procedure is being recorded in the water journals.

To test for water hardness, students will add drops of soap to the water samples, stopper the tubes, and shake the sample until they obtain a large volume of soap suds. (Students must agree on the amount of soap suds produced so that it is consistent from sample to sample.) The more soap required for suds, the harder the water. To accomplish this, add only one drop of soap to a tube at one time. Add the drop, stopper the top, and shake! If suds appear, measure the height of the suds above the water immediately after shaking stops. Record the results. If no suds form, add another drop of soap, stopper the top, and shake again. Repeat this process until measurable amounts of suds form, keeping track of the number of drops of soap required. Use this procedure for all samples tested.




Each group should record and discuss their results. Pose some questions to them: Which water was hardest? Which was softest? How do the different samples compare? Which would they say would cause the least damage to water pipes? Which would they not want to use for washing soap from their hair?

### *Activity 10: Does It Sink In?*

*In this activity students build a model for studying the movement of ground water. They simulate the application of chemicals (e.g., insecticides, herbicides, and fertilizers) on surface soils and follow that chemical as it infiltrates subsurface rocks and enters the model aquifer. Students get a chance to examine consequences of ground water movement.*

The next three activities use specially constructed containers to model ground water flow (Figure 5). These can be purchased commercially through the usual supply catalogs. Or, they can be made in your school. (Perhaps the technology teacher can assign them as a student project.) The basic design for the container uses clear acrylic

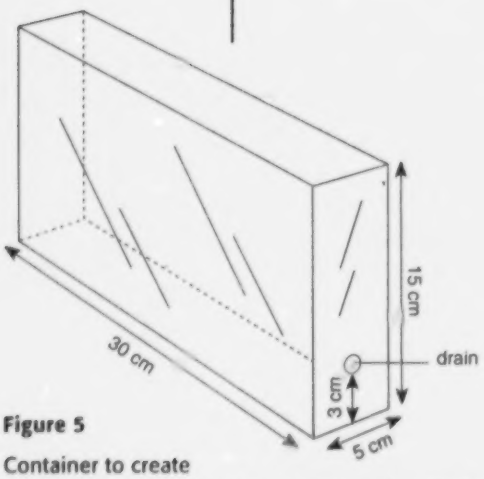



**Figure 5**

Container to create ground water models for activities 10 and 11.

plastic panels glued together to form a rectangular box. The ideal dimensions for this box are 30 cm long, 15 cm high, and 5 cm wide. (Keep the box thin to keep observations simple.) To this box, drill a drain hole on one of the thin sides, approximately 3 cm from the base. Match the size of the drain hole to the size of an available rubber stopper or plug. You'll also need to purchase enough pea-sized gravel to fill each tank about three-quarters full. Wash this gravel and allow it to dry before the activity. Each model also will need a pump dispenser (from a soft soap or hand lotion container) as well as a spray bottle filled with tap water. For this activity, you also will need one clear plastic cup for each group and samples of powdered drink mix; choose a mix that produces a dark-colored liquid. (For safety and clean-up, use mixes containing no sugar.)

Before continuing, ask students to compare their model with the "Ground Water" poster. Can they visualize the basic elements: zone of saturation, water table, permeable rock, etc.? Have them draw the model in the water journals, labeling parts matching elements labeled in the poster. Do they have a model aquifer?

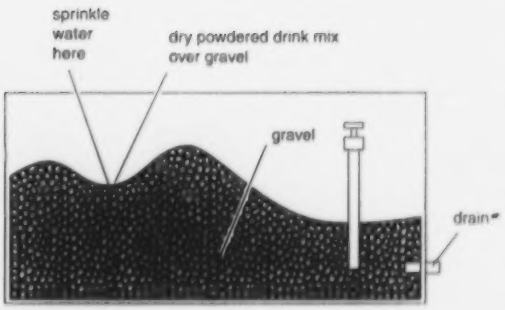



**Figure 6**

Fill each box about two-thirds full with gravel. To create a lake, mold gravel into hills and valleys.

The first use of their model will be to investigate how chemicals applied to the ground—fertilizers, pesticides, and herbicides—can enter ground water supplies. Give each group an envelope or spoonful of powdered drink mix and ask them to "apply" the chemicals to the surface near the uphill end of the gravel. Once the application is made, have one student in each group, the rainmaker, use the spray bottle to wash over the drink powder. (Note: Instead of spray bottles, you can use paper cups that have had evenly distributed, medium-sized holes punched into the bottom.) Reinforce the role of this "rain" in the water cycle. Ask each group to observe the movement of the powder into the gravel, just as chemicals infiltrate into the soil. Be sure observations are recorded in their journals. Continue to sprinkle water into the mix until the water table rises to the height of one-half the pump tube. What's happening to the water in the aquifer?

Simulate discharge from a well by pressing the pump 20–30 times. Catch the discharged water in the clear plastic cup. Ask each group to describe the water quality of the sample compared to the tap water they started with. (It might be useful to have a "control" sample on display.) Ask students to describe the movement of the pollution through the aquifer. What happened to the quality of the water in the lake? Take another sample after a few minutes. Is there a change in the sample quality?

Questions for group discussion might focus on the path of the applied chemicals through the underground water cycle. Where does it go? Or focus on the lake-end of the model. If this were a real case of chemical application, what would happen to the people drinking from that well? Can they think of real life cases to fit this model?

Before cleanup, ask each group to play the role of a water-quality expert. If they were presented with this situation in a real aquifer, how would they clean it up, e.g., how would they extract the chemical from the aquifer so it would be safe? If time permits, have them try their idea. Be sure their classmates check to see the solution is practical.

To prepare the material for later use, collect the spray bottles, cups, and pumps. Have the groups pour their gravel and water into a large bucket for rinsing. Each group should rinse their boxes and dry them with reusable clothes.

## *Activity 11: Can We Leave Things Buried and Forgotten?*

*This activity continues the modeling of ground water movement by investigating how different types of unsafe waste handling can affect water quality.*

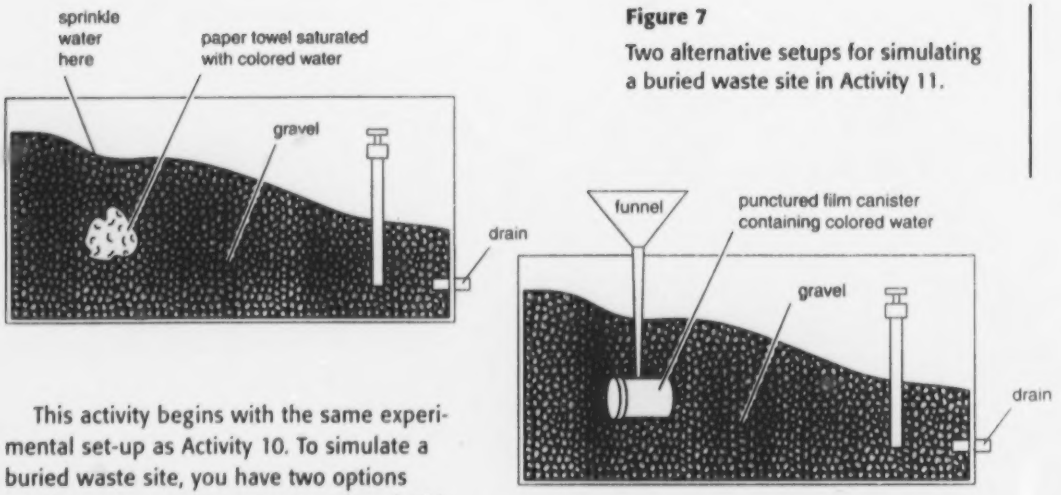



**Figure 7**
Two alternative setups for simulating a buried waste site in Activity 11.

This activity begins with the same experimental set-up as Activity 10. To simulate a buried waste site, you have two options (Figure 7). One uses a paper towel soaked in a solution of food coloring. This option is simple to equip: give each group a paper towel, a dropper bottle of food coloring, and a small cup one-third filled with water. Have them color the water then soak the paper towel. The second option uses a punctured film canister into which a solution of food coloring can be poured.

Distribute 35-mm film canisters that have been punctured several times and that have one hole in their sides large enough to insert a straw. This canister will be buried in the gravel, with the tube exposed above the gravel. The canister simulates a cracked storage tank. Use the tube for filling the tank as might happen at a fill-up station.

At the start of this experiment, ask each group to rebuild their model, with the same type of slope as in Activity 10. Once they have created their waste material, have these buried 5–7 cm below the surface on the uphill end of slope. If the paper towel is used, have each group's "rainmaker" apply rain to the model as in the previous activity. If the canister option is used, ask each group to pour colored water into their underground storage tanks. Add enough water to replace the capacity of the canister twice.

While this process takes place, the rain maker should sprinkle the surface using the water bottle. (Note: Instead of spray bottles, you can use paper cups that have had evenly distributed, medium-sized holes punched into the bottom.)

After the water table rises to half the depth of the well tube, press the pump 20–30 times, collecting the sample in a plastic cup. Compare the resulting water with the tap water used for the original filling of the aquifer. Record the results and discuss the events taking place in the model as they involve threats to water quality. How can damage to the aquifer be prevented in these cases?

## *Activity 12: Can We Keep a Landfill Filled?*

*This activity provides students with an opportunity to solve a water-quality problem using these models and their understanding of ground water movement.*

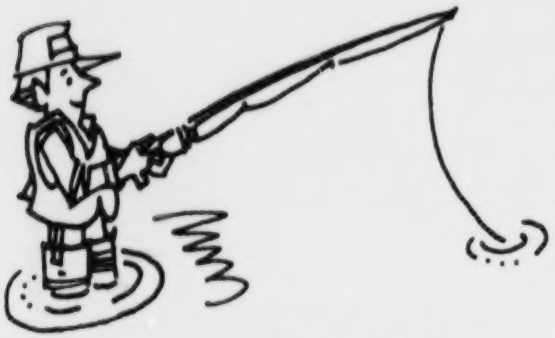
Creative problem solving is a skill of fundamental importance. In this activity, ask students to begin by creating the ground water model as in Activities 9 and 10, leaving a hole into which another waste sample will be dumped. Once the basic model is arranged, present each group with either a saturated paper towel or a leaking canister as in Activity 10. Tell them that now is their chance to solve the water quality problem before it starts. In five minutes, they're going to bury this waste material in the model's dump site. Their job is to design a dump that can safely store the waste and not pollute the ground water. Have a variety of materials available to use in constructing their dump site—e.g., sheets of different materials, strips of foam, cardboard, fabric, soil, pebbles, etc.—though be sure to use materials that would have an analog in a real dump site. Be sure

students record in their water journals the solution they attempted as well as any other ideas they think might work.

When the experiment storage sites are prepared, bury the waste as promised and repeat the experiment as in Activity 10. Did the solution work for the short term?

Now add a complication. Many plausible solutions to safe burial sites work in the short term, but lose their protective qualities over time as buried chemicals degrade the containers and liners and as natural processes of decomposition (sometimes these even include burrowing animals) thin protective layers.

You can play "nature" in each group's model by shifting the gravel and compressing it. Reproduce the actions of burrowing animals and chemical degradation by sinking a poker into the gravel at random locations and random depths. Have students roll the pebbles around with their fingers to simulate erosion. Maybe add an earthquake or a tube-laying project across the model. Explain how these are intended to simulate the long-term future of the dump site.



Before studying the effects of this activity, ask each group what they would have done differently, if anything, had they known what was going to happen to their dump site. Have each group repeat their testing of the site by adding more "rain" and testing the water from the pump. How did their experimental landfill survive the demands of nature? What would they recommend be done with landfills and underground storage tanks so they keep polluting materials contained? In a class discussion, discuss student impressions about what solutions would be realistic for a landfill that serves a medium-sized or large city.



# Let's Do More Research

Many additional activities can be included in your water resources curriculum. This section provides topics for student assignments, science fair projects, and supplemental investigations.

## *More Navigation Research*

• Investigate why people build locks along rivers. How do locks work? Who operates them? Have any of your students visited or traveled through one? Arrange a field trip, a visit by a lock operator, or suggest a family outing.

• Investigate how engineering and construction teams build canals. These great projects have political dimensions, too. By treaty, the United States, which has administrated the Panama Canal since its opening, will transfer that responsibility to Panama in 1999. Was this treaty the right decision? Hold a class debate.

• Collect information about what boat traffic moves through a major canal, such as the Panama or Suez Canal. How does the canal save time and money? Who pays to use it?

• Investigate who manages waterway traffic. Are rivers run the same as highways are, with speed limits and signs? What would you have to know to be a riverboat captain?

• Investigate the ways some cities—e.g., New Orleans, Chicago, Minneapolis, Portland, Galveston—were first built along waterways.

• Navigating in the ocean is no easy task. How do people find their way while at sea? How is this different now compared to one hundred or two hundred years ago? What sorts of obstacles are there at sea that ocean-going ships and barges need to be aware of?

• What steps do maritime authorities and shipping companies take to protect the environment? Is loading and off-loading done in environmentally safe ways? Can your students suggest improvements? If a shipwreck or major spill were to occur, what equipment do shipping companies have ready to respond?

• Investigate how captains navigate along waterways? Where do the maps and navigational charts come from? How do you read them? What other technologies do they use?

• Investigate the management of harbors. What goes into their operation? Who owns and operates harbors (is their management like airports, railroads, and highways)? In the harbor you investigate, learn what cargoes typically move through it. Where do these materials and goods come from? Where are they going?

• Waterways are the most important means of transportation in some parts of the world. Investigate the role water highways have for people living in the Amazon rain forest, along the Nile River, in the Netherlands, in the Louisiana bayou country, on islands in Puget Sound, Washington, and in Inuit communities near the Arctic Circle. How does your style of transportation compare with theirs?

• Boating is big business in the United States and is not without problems or controversies. In some communities, homeowners and campers complain about noise from jet skis and powerful motorboats. Is this a problem near you? Are there any boating-related problems in your community? Encourage students to locate existing problems, then suggest solutions.

• As a weekend project, have students make an "origins list" for manufactured items in their home. Because home materials vary widely, this kind of assignment is best left loosely structured. Remember, this search through the home can be another avenue for parental involvement. Regardless of how students collect their data, ask for a summary report of their results in a way that links their lives to world geography.

You may also wish to give students page-sized maps of the world and ask them to color in countries supplying materials to their lists. (You will need to have either a wall map or atlases on hand for locating unfamiliar places.) Nearly all goods imported into the United States come to this country via water highways. As students compare their maps or reports, they will learn how connected Americans are to the rest of the world.

### *More Ground Water Research*

• Investigate how hydrologists locate ground water. How do they measure aquifers and follow water flow underground?

• Have students research the use of divining rods to locate ground water. They can then debate the accuracy and usefulness of such techniques.

• Are there large aquifers in your area of the country? Who draws water from them and in what amounts? Is there a balance between recharge and discharge?

• People living in areas where underground water is difficult to reach "harvest" rainwater and runoff. Investigate how they go about doing this. Is it a good way to conserve underground supplies?

• Consider issues of "intergenerational fairness"—the idea that conservation steps should be taken now in fairness to future generations of water users. How should a community decide what is fair when balancing between present and future needs? Who should we be fair to?

• In the last two decades, cities in the American southwest have grown considerably. Investigate several cities. How has their growth changed water demands and water supply? Many of these "desert metropolises" rely partially on aquifers to supply the water needs of industry and people. Are their rates of discharge and recharge balanced? Is their rate of water use wise, given the availability of alternative water supplies?

• Increasing salt concentrations, resulting from *saltwater intrusion* is a growing problem with aquifers along the United States coastlines. Investigate the causes and solutions. How does salinity affect water use? What are the economic consequences of this problem, and what can people do about those consequences?

• A number of scientist teams are experimenting with ways to "artificially" recharge aquifers by pumping surface water into the ground. Investigate how this is done. Where does the water come from? What are the advantages of storing water underground instead of above ground?

### *More Water Quality Research*

• Investigate who evaluates water quality in your area. Assign one water quality problem—biological, chemical, or physical—to each student and ask them to investigate it in detail: What are the safe levels? Why is the pollutant a hazard to water quality? What are the risks of each problem?

• Concern about safe drinking water is behind many people's turn to bottled water. But how clean is bottled water? Do different kinds of bottled water meet the same standards? How can you find out this information? Where do bottlers of processed drinks—e.g., soda pop and sports drinks—get their water?

• Sample the water in your school, nearby stream or pond, etc. for its quality and possible sources of contamination. (This will involve sending samples to testing labs. Nitrates and bacteria are the cheapest and most common substances for which to test.) If unusual results are obtained, alert officials in your school district.

• Lead in drinking water is a major water-quality issue. Where does lead in water come from? What can be done about this? Are there simple steps that can be taken to reduce lead exposure? How much lead does the water in your school contain? How can you find this out?

• Investigate one local water quality issue, such as a manufacturing facility or an abandoned gas station, as point sources of contamination. What are the problems and what can your students suggest to resolve them?

• Visit a local gas station, oil change center, or construction site. What is done to prevent or reduce contamination of the water supply? Can your students suggest additional steps and educate the owner about water-quality issues?

• Follow the pipes. Where do the storm drains on your street go? Do they drain into a nearby river, lake, or inlet? Explore the opportunities to increase awareness in your community about these connections. Some communities, for example, allow students to paint "drains into river" warnings on storm drains. (Be sure to check with community officials before beginning such a program.)

• A number of groups within the U.S. are struggling to reduce the presence of acid rain. Look up state and federal laws regarding acid rain and other clean water issues. Investigate the local consequences of clean water laws. Have students write letters to their elected representatives to express their opinions on these water-quality issues.

• The global nature of shipping means that waterborne organisms can be carried from one region of the world to another. Have several students investigate how this transferrence happens, such as with zebra mussels in the Great Lakes. How much of a problem is this? What are researchers doing to prevent it?

# Resources

Many state and federal agencies supply educational materials for navigation, ground water, and water quality topics. So do many non-profit associations and private organizations. Consult the government pages of a telephone directory or a library for nearby offices. Or, write your state delegates and representatives for information on who to contact for specific issues. Another good place to start is your state's department of natural resources. The Internet has hundreds of sites regarding navigation, ground water and water quality—try a web search using key words used in *Water Matters*. Listed below are a number of other informative organizations.

U.S. Army Corps of Engineers
20 Massachusetts Ave., NW
Washington, DC 20314
202-761-0660
www.usace.army.mil

U.S. Geological Survey
Water Resources
12201 Sunrise Valley Dr.
Mail Code 419
Reston, VA 22092
800-h2o-9000
www.usgs.gov

U.S. Environmental Protection Agency
Office of Water Resource Center
401 M St., SW
Washington, DC 20460
202-260-7786
www.epa.gov/OW

National Research Council
Water Science and Technology Board
2101 Constitution Ave., NW
Washington, DC 20055
202-334-3422
www.ww2.nas.edu/wstb

American Rivers
1025 Vermont Ave., NW, Suite 720
Washington, DC 20005
202-547-6900
www.igc.apc.org/amrivers/

American Water Resources Association
950 Herndon Ave., Suite 300
Herndon, VA 20170
703-904-1225
www.awra.org/~awra

American Water Works Association
6666 West Quincy Ave.
Denver, CO 80235-3098
800-926-7337
www.awwa.org

The Groundwater Foundation
PO Box 22558
Lincoln, NE 68542-2558
402-434-2740

Water Environment Federation
601 Wythe St.
Alexandria, VA 22314-1994
703-684-2492
www.wef.org

## *Related Publications from NSTA*

The following resources can be ordered by contacting NSTA Publications and Sales, 1840 Wilson Blvd., Arlington, VA 22201-3000. You can also call 1-800-722-NSTA (for book sales) or 703-243-7100 (main number) from 9 a.m.–5 p.m., EST. When ordering, be sure to have the book title and publication number available.

Published by NSTA

- Jack Gartell, Jr., Jane Crowder, and Jeffrey Callister, *Earth: The Water Planet*, 1992. Wide range of hands-on activities for water-related topics. Grades 6–10, 204 pp., #PB076X.

- Sue Cox Kaufman, *Water Matters, Volume 1*, 1994. Addresses Wetlands, Water Use, and Wastewater Treatment. Includes background information, 12 activities, and dozens of ideas for incorporating water education into your curriculum. Grades 3–8, 32 pp., #PB116X1.

- Karen K. Lind, ed., *Water, Stones, & Fossil Bones*, 1991. Choose from a variety of fun activities such as measuring raindrops and cooking hot dogs on a solar cooker. Grades K–8, 140 pp, #PB089X.

- P. Sean Smith and Brent A. Ford, *Project Earth Science: Physical Oceanography*, 1994. Focuses on the uniqueness of water, how it effects Earth's oceans, and the forces that cause currents, waves, and tides. Includes a section on the effect humans have on marine environments. Grades 5–10, 224 pp. #PB114x.

• Bob Tierney, *How to Write to Learn Science*, 1996. Shares ideas for using journals to teach science. A variety of exercises focus on building trust in the classroom. Students learn how to express, rather than memorize, science. Grades 7–12, 24 pp., #PB038x9.

From other publishers

• Michael Caduto, *Pond and Brook*, 1990. Hands-on projects and activities introduce the intriguing, largely unseen world of freshwater habitats. Grades 7–12, 288 pp., #OP173X.

• Mark K. Mitchell and William B. Stapp, *Field Manual for Water Quality Monitoring*, 1994. Provides monitoring options and activities that are both inexpensive and require little technology. Grades 10–12, 272 pp., #MS082X.

• Mark K. Mitchell and William B. Stapp, *Field Manual for Global Low-Cost Water Quality Monitoring*, 1995. Designed to educate students and the public about the necessity for clean river water. Grades 9–12, 335 pp., #MS082X2.

## *Additional Publications*

• William Alley (ed.), *Regional Ground Water Quality*, 1993. Technical reference volume with extensive coverage of water-quality topics, research methods, and case studies.
Van Nostrand Reinhold
115 Fifth Ave.
New York, NY 10003
800-842-3636

• William Ashworth, *The Encyclopedia of Environmental Sciences*, 1991. Good for short, easy-to-understand explanations of technical terms.
Facts on File
11 Penn Place, 15th Floor
New York, NY 10001
800-322-8755

• Peter Gleick (ed.), *A Guide to the World's Freshwater Resources*, 1993. A wealth of data on global water availability, etc. Essays arguing water issues will be central to life in the 21st century.
Oxford University Press
198 Madison Ave.
New York, NY 10016
800-451-7556

• Blaine Harden, *A River Lost: Life and Death of the Columbia*, 1996. Case study focusing on the Columbia river system.
W.W. Norton
500 Fifth Ave.
New York, NY 10003
800-233-4830

• Eric Jorgensen (ed.), *The Poisoned Well: New Strategies for Ground Water Protection*, 1989. Handbook for community and personal action on ground water issues from the Sierra Club Legal Defense Club.
Island Press
1718 Connecticut Ave., NW
Suite 300
Washington, DC 20009
800-828-1302

• David Kromm and Stephen White (eds.), *Groundwater Exploitation in the High Plains*, 1992. Detailed study of the High Plains aquifer, including problems, legal issues, management techniques, and future prospects.
University of Kansas Press
2501 West 15th St.
Lawrence, KS 66049
913-864-4155

• E. Willard Miller and Ruby Miller, *Water Quality and Availability: A Reference Handbook*, 1992. Good reference source on basic water laws, regulations, and organizations.
ABC-Clio
P.O. Box 1911
Santa Barbara, CA 93116-1911
800-368-6868

• National Research Council, *Sustaining Our Water Resources*, 1992. Includes good descriptions of navigation and dam systems in the U.S.
National Academy Press
2101 Constitution Ave., NW
Washington, DC 20055
800-624-6242
www.nap.edu

• Steve Vandas, *USGS Water Resources Professionals Outreach Notebook, Ground Water*. Educational reference provides easy-to-understand overview of basic ground water issues, plus five lesson plans for students in grades 6–8.
USGS—Branch of Information Services
Box 25286
Denver, CO 80225
800-435-7627

# Acknowledgments

## *About the National Science Teachers Association*

The National Science Teachers Association is the world's largest organization dedicated to improving science education on all levels—preschool through college. Membership in NSTA brings educators into a vibrant organization of more than 53,000 science teachers, science supervisors, administrators, scientists, business and industry representatives, and others representing every facet of science education. NSTA conducts national and regional conventions that attract more than 30,000 attendees annually. NSTA provides many programs and services for science educators, including awards, professional development workshops, and educational tours. NSTA offers professional certification for science teachers in eight teaching levels and discipline area categories.

NSTA members choose among four journals, each for a specific grade level: *Science and Children* (elementary), *Science Scope* (middle level), *The Science Teacher* (high school), and *Journal of College Science Teaching* (college). NSTA journals feature lively, "how to do it" articles, commentary, research, colorful posters, and monthly columns. Two NSTA magazines designed for students, parents, and teachers—*Dragonfly* and *Quantum*—are available by subscription. NSTA's newspaper, *NSTA Reports!*, features news on education issues, teaching resources, funding opportunities, and more. Members receive a 10 percent discount on all publications in NSTA's Publications Catalog, which includes NSTA's publications plus more than 200 specially-chosen titles.

*Water Matters, Volume 2* is published by NSTA—Gerry Wheeler, Executive Director, and Phyllis Marcuccio, Associate Executive Director for Publications. The book was produced by NSTA Special Publications—Shirley Watt Ireton, (Managing Editor); Doug Messier (Associate Editor); Chris Findlay (Associate Editor), Jocelyn Lofstrom (Assistant Editor); Eric Knaub (Program Assistant), and Christina Frasch (Editorial Assistant). Artwork created by Frank Farrar Graphics, Denver, Colorado.

For more information about NSTA or any of its publications, call 1-800-830-3232 (membership); 1-800-722-NSTA (publication sales, North America); or 703-243-7100 (main number). We invite you to visit our web site at http://www.nsta.org, or email us at membership@nsta.org (membership); pubsales@nsta.org (Publication Sales); or spubs@nsta.org (Special Publications editorial).

## *About the United States Geological Survey*

As the nation's largest Earth science research and information agency, the USGS maintains a long tradition of providing "Earth Science in the Public Service." The USGS, a bureau of the U.S. Department of the Interior, was established to provide a permanent Federal agency to conduct the systematic and scientific "classification of the public lands and examination of the geological structure, mineral resources, and products of the national domain."

The mission of the USGS is to provide geologic, topographic, biologic, and hydrologic information that contributes to the wise management of the nation's natural resources and that promotes the health, safety, and well-being of the people. This information consists of maps, databases, and descriptions and analyses of the water, biological, energy, and mineral resources, land surface, underlying geologic structure, natural hazards, and dynamic processes of the Earth.

The *Water Matters* volumes and the corresponding poster series were developed through the *Water Resources Education Initiative*. Steve Vandas, of the Water Resources Division, is the Initiative's project chief. For more information about the Initiative or USGS, visit their web site at http://www.usgs.gov/ or write: U.S. Geological Survey, MS804 National Center, Reston, VA 20192, USA.

## *The Authors:*

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**Joe Cain** teaches history and philosophy of science at the College of London. He received his Ph.D. in the history of science from the University of Minnesota. Joe Cain has been the project editor on numerous NSTA publications, including *Water Matters, Volume 1*. He co-authored *Craters! A Multi-science Approach* and continues to write on pre-college and university-level science education topics.

### About Water Matters

These teacher's guides are developed around USGS water education posters on wetlands, water use, wastewater treatment, navigation, ground water, water quality, oceans, watersheds, and hazardous waste. Sort through dozens of activities and extensions to find hands-on learning experiences perfect for your classes. Whether for introductory use or a detailed curriculum unit on water education, you're sure to discover that the ***Water Matters*** volumes cover it all!

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NSTA

## *Poster Series*

This poster is the fourth in a series of water-resources education posters developed through the Water Resources Education Initiative. The Water Resources Education Initiative is a cooperative effort between public and private education interests. Partners in the program include the U.S. Geological Survey and U.S. Fish and Wildlife Service of the U.S. Department of the Interior, the U.S. Environmental Protection Agency, the American Water Resources Association, the Nebraska Groundwater Foundation, and the National Science Teachers Association.

The first completed poster in the series is entitled "Water: The Resource That Gets Used & Used & Used for Everything!" The second and third posters in the series are entitled "How Do We Treat Our Wastewater?" and "Wetlands: Water, Wildlife, Plants & People!" The posters in the series are designed to be joined together to create a wall mural. A schematic of the wall mural including the topics for the completed and planned posters is displayed on this panel. The lightly shaded spaces indicate the completed posters. The dark-shaded space is this poster.

| | | |
|---|---|---|
| **ICE/GLACIER or WATERSHEDS** | **HYDROLOGIC CYCLE** | **ACID RAIN or HAZARDOUS MATERIAL** |
| **WETLANDS** | **WATER USE** | **WASTEWATER TREATMENT** |
| **OCEANS or NAVIGATION** | GROUND WATER | **WATER QUALITY** |

Water-resources topics of the completed posters are drawn in a cartoon format by the same cartoonist. Posters are available in color or black and white. The reverse side of the color posters contain educational activities: one version for children in grades 3-5 and the other with activities for children in grades 6-8. The black-and-white posters are intended for coloring by children in grades K-2.

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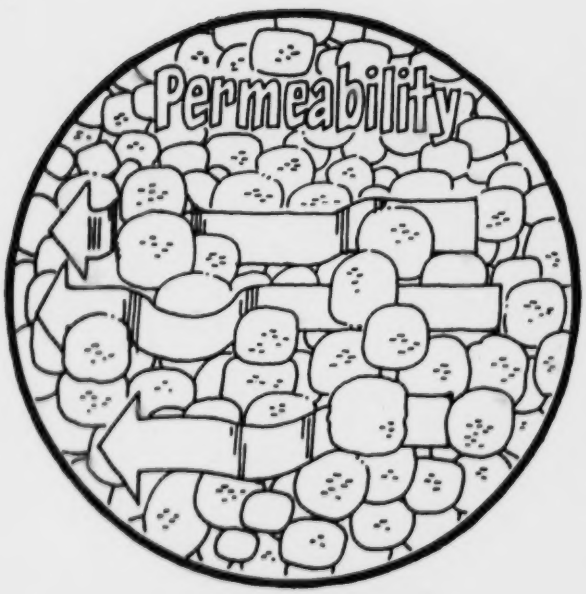
**Ground water is water underground in saturated zones beneath the land surface. Contrary to popular belief, ground water does not form underground "rivers." It fills the pores and fractures in underground materials such as sand, gravel, and other rock. If ground water flows from rock materials or can be removed by pumping from the saturated rock materials in useful amounts, the rock materials are called aquifers. Ground water moves slowly, typically at rates of 7 to 60 centimeters per day in an aquifer. As a result, water could remain in an aquifer for hundreds or thousands of years. Ground water is the source of about 40 percent of water used for public supplies and about 38 percent of water used for agriculture in the United States.**

**One of the largest aquifers in the United States is the High Plains Aquifer. The aquifer is approximately the size of California and is located under parts of South Dakota, Wyoming, Kansas, Nebraska, Colorado, New Mexico, Oklahoma, and Texas. The High Plains Aquifer contains an estimated 4 quadrillion liters (4 with 15 zeros after it) of water.**

**This poster depicts an unconfined or water-table aquifer. An unconfined aquifer is an aquifer where the water surface — water table — is free to rise and decline as water moves from recharge areas to discharge areas. Recharge areas are places where an aquifer receives its water. The recharge sources shown are a reservoir, a stream, and precipitation. Their titles are red. The arrows represent the movement of water from the recharge sources to the discharge areas. The large circle on the right-hand side of the poster is a representation of how recharge occurs from precipitation.**

**The left-hand side of the poster shows conditions in a ground-water discharge area. Discharge areas are where ground water flows to the land surface or to surface-water bodies such as the pond and river shown on the poster. Ground water also can discharge by pumping a well. The titles of these ground-water discharges are yellow.**

**The poster is folded into 8.5" x 11" panels; front and back panels can easily be photocopied.**




## Permeability

For water to move in an aquifer, the pores between rock materials and fractures in rock must be connected. If there is a good connection among pore spaces and fractures, water can move freely and we say that the rock is permeable. The capacity of rock material to transmit water is called permeability. Water moves through different materials at different rates — faster through gravel, slower through sand, and much slower through clay. Therefore, gravel is more permeable than sand, which is more permeable than clay.

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# Ground-Water Movement

## Introduction

Ground water must be able to move through underground materials at rates fast enough to supply useful amounts of water to wells or springs in order for those materials to be classified as an aquifer. For water to move in an aquifer, some of the pores and fractures must be connected to each other. Water moves through different materials at different rates, faster through gravel, slower through sand, and even slower through clay. Gravels and sands are possible aquifers; clays usually are not aquifers. The following activity demonstrates how different sizes of rock materials that make up an aquifer affect water movement.

## Objectives--Students will:

1. Identify several sources of rock materials that make up an aquifer.
2. Discuss how water moves through gravel, sand, and clay.

## Materials

1. At least 10 students.
2. Large area to conduct activity.

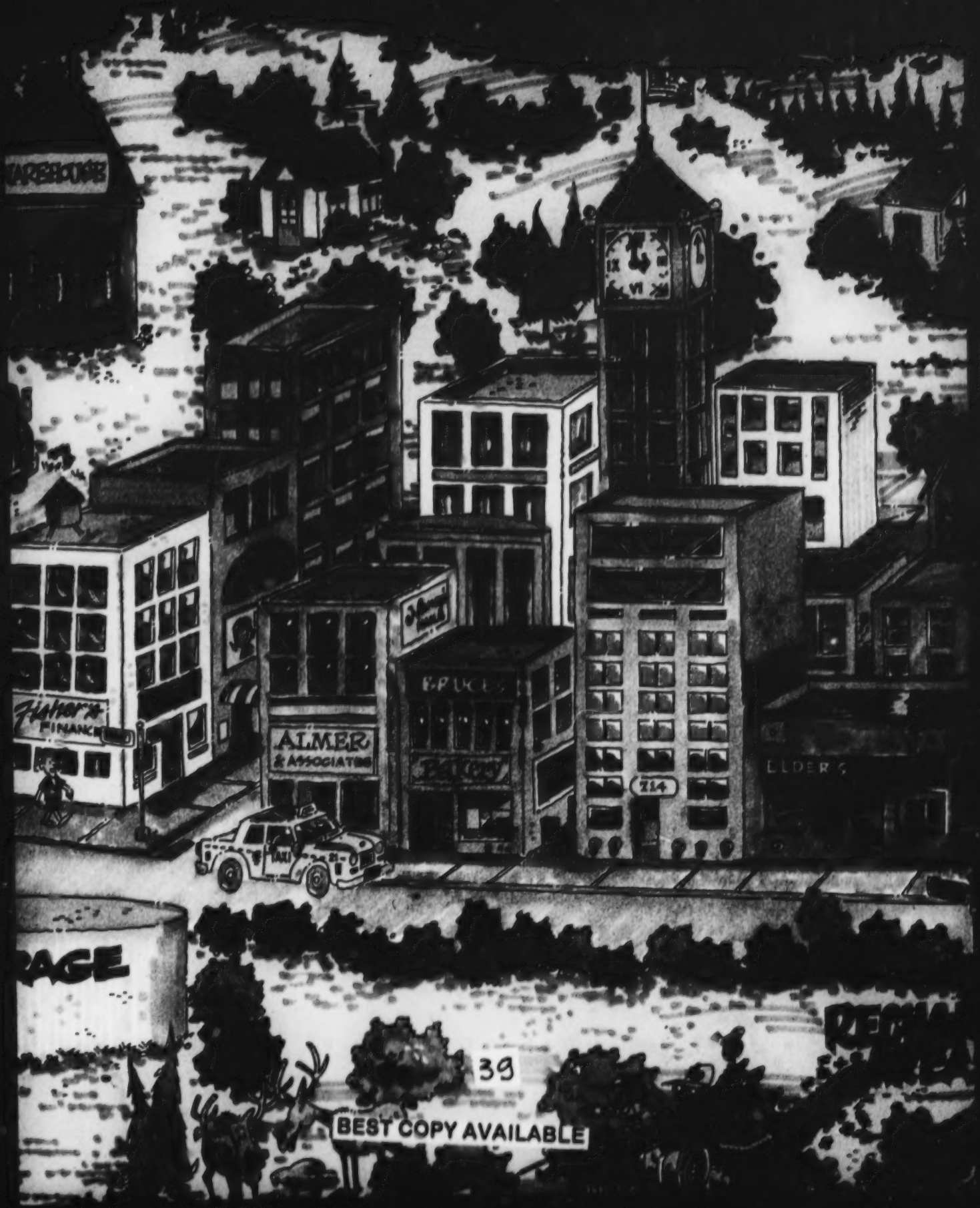
## Teacher Preparation

This activity can be conducted in the classroom, gymnasium, or outside the school building. If conducted in the classroom, move all furniture to allow for sufficient room for the movement of students. This is a three-part demonstration that may create some excitement.

## Procedures

Select two or three students to be molecules of water. The remaining students will be rock materials.

1. **Activity One:** Water movement through gravel. The students represent gravel by holding arms outstretched, leaving a 15- to 30- centimeter (cm) space between their outstretched arms. Locate these students in the center of the activity area. The students representing water molecules are to start on one side of their "gravel" classmates and move through them, exiting on the other side. The water molecules will move easily through the gravel.



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2. **Activity Two:** Water movement through sand. The students represent sand by extending arms, bending them at the elbows and touching their waists with their fingers. Locate these students in the center of the activity area, spacing them approximately 15 cm apart. Once again, have the water molecules slowly make their way through their "sand" classmates. The water molecules will experience some difficulty, but should still reach the other side.

3. **Activity Three:** Water movement through clay. Students become clay particles by placing their arms straight down the sides of their bodies and standing approximately 10 cm apart. Locate these students in the center of the activity area. It will be a formidable task for water molecules to move through the clay. Without being rough, the water molecules should slowly make their way through the clay. The water molecules may not be able to move through the clay at all.

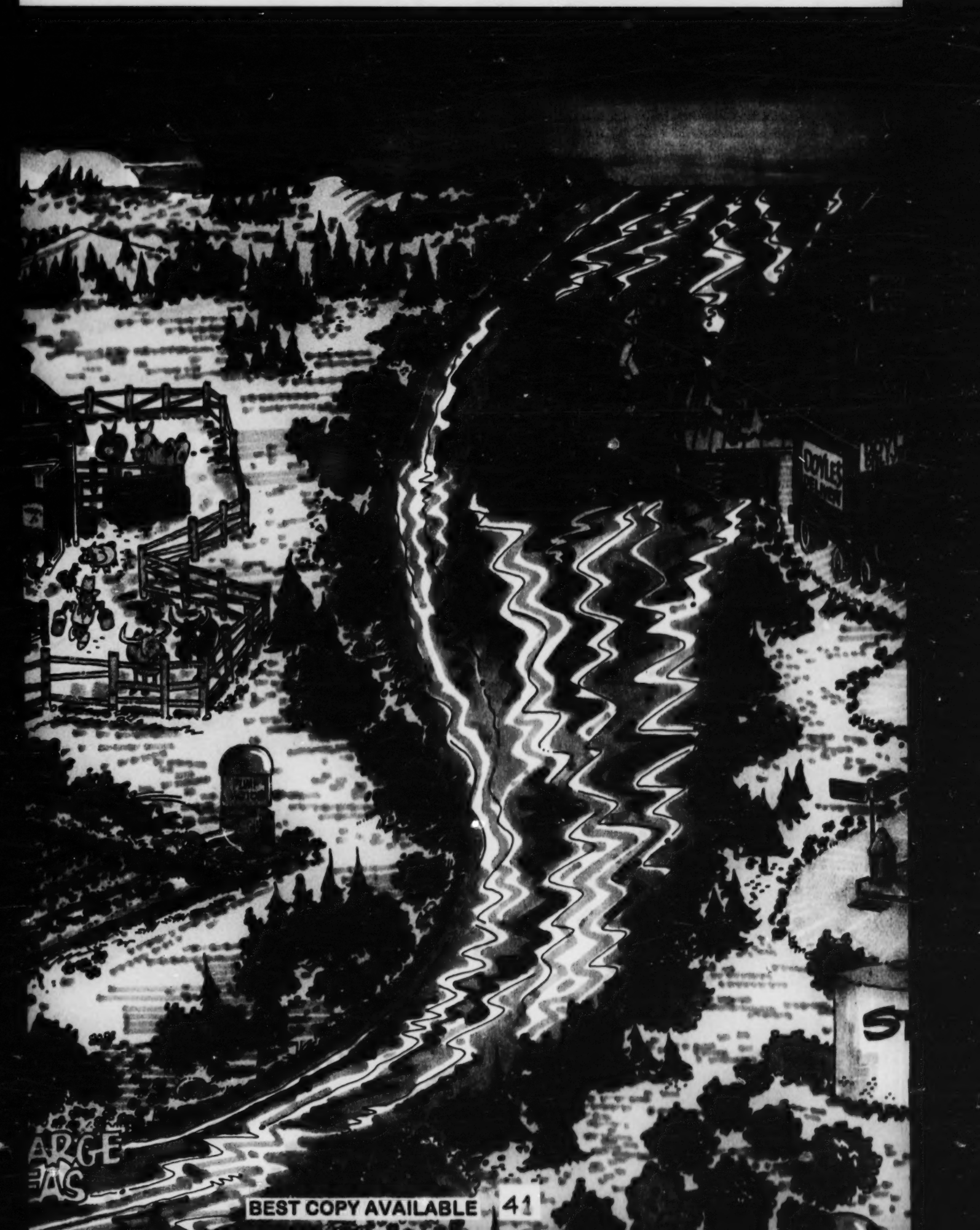
## *Interpretive Questions*

1. Which one of the materials — gravel, sand, or clay — was the easiest for the water molecules to move through? (Answer: Gravel, then sand, then clay.) Why? (Answer: Because there are larger spaces between the gravel particles.)
2. If there were three rock units, one of gravel, one of sand, and one of clay, all containing the same quantity of water, in which would you drill a well? (Answer: Gravel. Water moves easier through gravel than sand or clay.)

## *Extension*

Obtain 250 milliliters (mL) of sand, 250 mL of pea-size gravel, 250 mL of clay, and three large funnels (top diameter approximately 12 cm). Force a piece of cheesecloth into the top of the spout of each funnel. This will prevent material from going through the funnel spout. Put each funnel into separate clear containers so that the spout of the funnel is at least 5 cm above the bottom of the container. Pour the sand into the first funnel, pea-size gravel into the second funnel, and the clay into the third funnel. Pour equal amounts of water (approximately 200 mL) onto the materials contained in the funnels. Select three students to pour the water, creating a permeability race. Time how long it takes the water to flow through the materials. Record on a data sheet. Which material did the water flow through the fastest? Why?

***This activity was adapted from "Get the Ground Water Picture," National Project WET.***



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# ACTIVITY
# Recharge - Discharge

## Introduction

Recharge is the addition of water to an aquifer. Recharge can occur from precipitation or from surface-water bodies such as lakes or streams. Water is lost from an aquifer through discharge. Water can be discharged from an aquifer through wells and springs, and to surface-water bodies such as rivers, ponds, and wetlands. The following activity is designed to demonstrate the recharge and discharge of water to a model aquifer.

## Objectives--Students will:

1. Identify several sources of recharge for ground water.
2. Identify several sources of discharge for ground water.
3. Discuss how water moves from recharge to discharge areas.
4. Discuss the connection between surface water and ground water.

## Materials

1. One clear container at least 15-cm wide x 22-cm long x 6-cm deep for each group. Possible containers include clear plastic salad containers or clear baking pans.
2. Sufficient pea-size gravel to fill the container approximately 2/3 full.
3. Two 472-mL paper cups for each group.
4. One pump dispenser from soft-soap or hand-lotion containers for each group.
5. 472 mL of water.
6. Grease pencils, one for each group.
7. Twigs or small tree branches, to represent trees on the model (optional).
8. Colored powdered-drink mix or food coloring (optional).

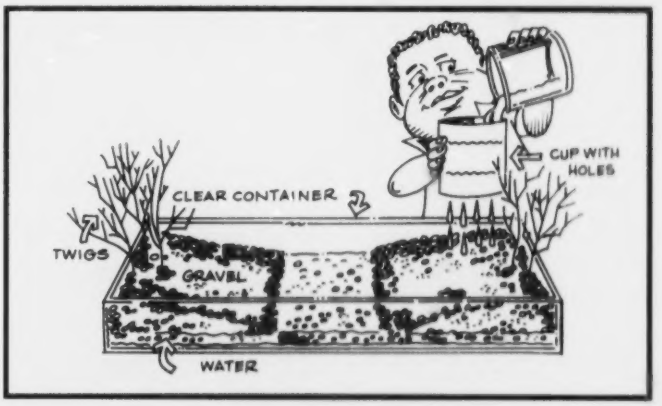
## Teacher Preparation

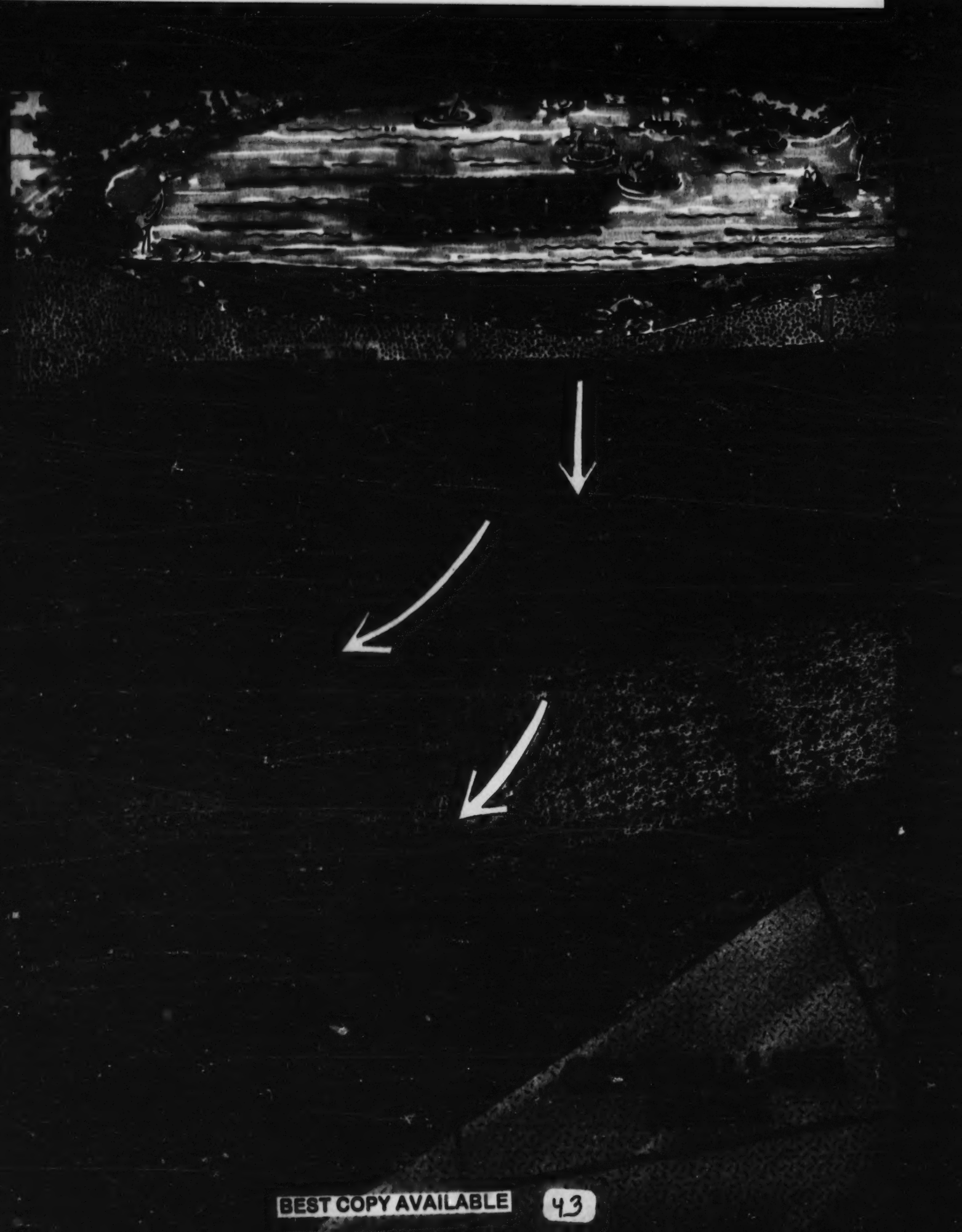
1. Display a copy of the poster titled "Ground Water: The Hidden Resource" on the classroom wall several days prior to conducting this activity.
2. Using an ice pick or awl, punch 8 to 10 small holes in the bottom of one of the paper cups. When filled with water, this cup will be used to simulate rain.
3. Fill the clear containers 2/3 full with pea-size gravel.

## Procedure

- Divide the class into small groups. Provide each group with one clear container filled 2/3 with pea-size gravel, one 472-mL cup with holes punched in the bottom, one 472-mL cup with no holes, and one pump dispenser.

- Students make models to represent hills and a valley. One student from each group fills the 472-mL cup without holes in the bottom with water. Each group makes a valley in the center of the model by pushing gravel to the farthest opposite ends of the container so the valley extends completely across the width of the container. About 2 cm of pea-sized gravel remains in the bottom of the valley.





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- Explain to the students that the gravel mounds on both sides of the container represent hills with a valley in between. The students can place twigs or small branches on the hills to represent trees. Instruct a student to hold the 472-mL cup with holes over the model. Then add 472 mL of water to this cup. Tell the students that they are simulating rain. Have the students observe how the water infiltrates into the gravel and becomes ground water.

- Introduce the word recharge — the addition of water to the ground-water system. Observe that water is standing in the valley. Have the students use a grease pencil to draw a line identifying the water level in the container. The line should traverse the entire model, identifying the water level under the hills and in the valley. There will be a pond in the valley.

- Explain that they have just identified the top of the ground water in their model. The top of the ground water is called the water table. Discuss with the students how the ground water becomes a pond in the valley. This is because the water table is higher than the land surface (gravel) in the valley.

- Have the students insert the pump into one of the hills on the side of the valley, pushing the bottom down to the ground water. Allow each of the students in the group to press the pump 20-30 times after the water in the pump has begun to flow. Catch the water in the paper cup with no holes in the bottom. After each student takes a turn pumping, instruct them to observe the location of the water table in relation to the grease-pencil line. Where did the water go? What happened to the pond? Discuss discharge, the removal of water from the ground. Discuss the effect of ground-water pumping on streams and lakes.

## ***Interpretive Questions***

1. Where does ground water come from?

**Answer:** Precipitation (rain, snow, sleet, etc.) Also, if the water table is at or below the surface of the water in a stream or pond, water can move from the stream or pond to recharge the ground-water system.

2. What would happen in the students' neighborhood (name a local stream or pond) if a well was drilled near that stream or pond and enough water pumped to lower the water table around the stream or pond?

**Answer:** Some water from the stream or pond would be removed by the pump through the well. If enough water is removed, a pond or small stream could go dry.

## ***Extension***

Sprinkle a colored powdered-drink mix or food coloring on top of one of the hills and repeat the above activity by having it rain on the model. Discuss the movement of "pollution" from the hill to the ground water to the lake.

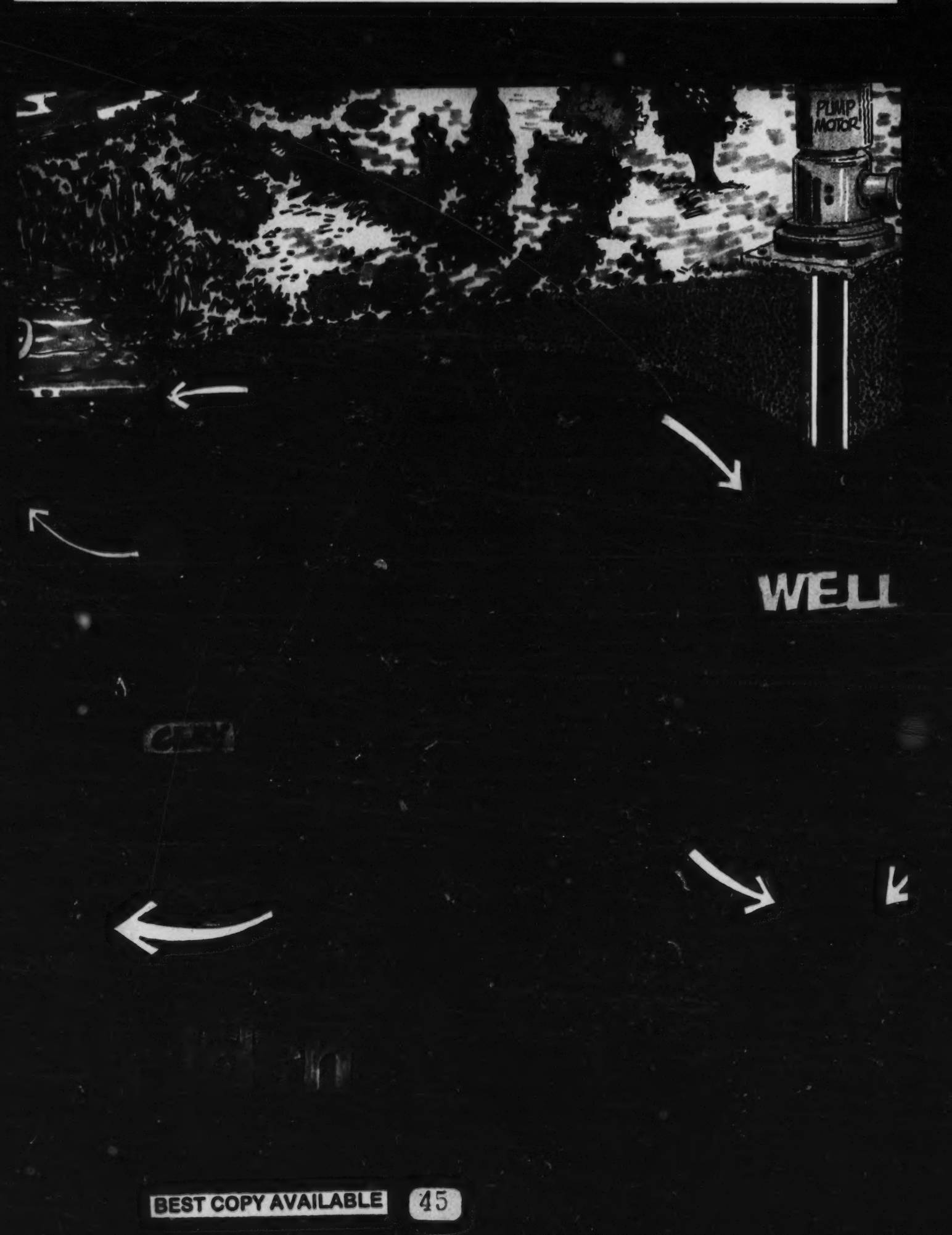
---

## ***ORDERING INFORMATION***

Single copies of the first three posters in the series (see Poster Series panel) and a limited supply of the "Ground Water" poster (color for grades 3-5 and 6-8 or black and white) can be obtained at no cost from the U.S. Geological Survey.

U.S. Geological Survey
Box 25286
Denver Federal Center
Denver, CO 80225
Telephone: (303) 236-7477

Also, the poster entitled "Water: The Resource That Gets Used & Used & Used for Everything!" has been translated into Spanish. A limited supply of color or black-and-white copies can be obtained at no cost from the U.S. Geological Survey at the above address.

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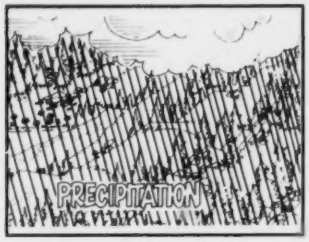
# Recharge Areas



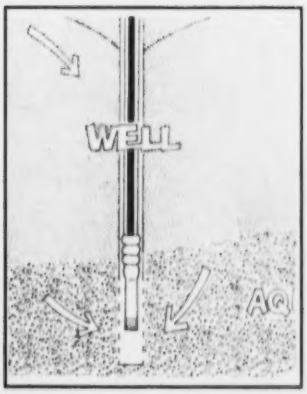

Recharge is the addition of water to the ground-water system. The recharge of freshwater begins as precipitation. Precipitation occurs in several forms, including rain, snow, and hail, but only rain is displayed on the poster. Some of the rain infiltrates into the soil. If the rate of the rainfall exceeds the rate of infiltration, surface water will flow over the land surface to surface-water bodies such as rivers and streams.

Water can infiltrate faster from the land surface into sandy soils than silty or clay soils. Water infiltrates into the soil and the unsaturated zone. The unsaturated zone occurs immediately below the land surface and contains both water and air in the pores and fractures in the rock materials. Water moves, or percolates, down through the unsaturated zone to the saturated zone. The saturated zone is where all the pores or fractures in rock materials are filled with water. The top of the saturated zone is called the water table.

Because surface-water and ground-water systems are connected, surface water can recharge ground water. Aquifers can obtain water from such surface-water bodies as reservoirs and streams when and where the water table is lower than the surface-water body. Recharge areas usually are higher in elevation than discharge areas.

# Discharge Areas

Places where ground water flows from aquifers to springs, seeps, wetlands, ponds, or streams are called ground-water discharge areas. Ground-water discharge to these natural areas occurs when the water surface of the aquifer (water table on the poster) is at or above the elevation of the discharge area (river and pond on the poster). Surface-water and ground-water systems are interconnected. The flow of most streams is sustained by ground water seeping into the stream. The water surfaces of many ponds and wetlands are an extension of the local ground-water table. Springs occur where ground water flows from an aquifer to the land surface.




Ground water can be brought to the land surface by pumping from a well. A well is an opening that has been drilled or dug into an aquifer below the water table. Water from the aquifer flows into this opening to replace water removed by pumping water from the well. The water table slopes from areas of recharge to discharge areas like rivers, ponds, wells, and springs.

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Supplies of the first three posters may be purchased from:

American Water Resources Association
5410 Grosvenor Lane, Suite 220
Bethesda, MD 20814-2192
Telephone: (301) 493-8600

National Science Teachers Association
3140 N. Washington Boulevard
Arlington, VA 22201
Telephone: 1-800-722-NSTA

For information concerning ground-water educational materials contact:

Nebraska Groundwater Foundation
P.O. Box 22558
Lincoln, NE 68542-2558

## DEFINITIONS

**Aquifer** - An underground body of porous sand, gravel, or fractured rock filled with water and capable of supplying useful quantities of water to a well or spring.

**Crystalline Rock** - Igneous or metamorphic rock consisting of relatively large mineral grains.

**Freshwater** - Water that contains less than 1,000 milligrams per liter of dissolved solids.

**Ground Water** - Water beneath the land surface in the saturated zone.

**Ground-Water Discharge** - The flow or pumping of water from an aquifer.

**Ground-Water Recharge** - The addition of water to an aquifer.

**Infiltration** - Movement of water from the land surface into the soil.

**Permeability** - The capacity of porous rock for transmitting water.

**Public Supplies** - Water supplied for domestic, commercial, thermoelectric power, industrial, and other public uses.

**Saturated Zone** - Zone below the land surface where all the pores or fractures are filled with water.

**Surface Water** - Water on the Earth's surface.

**Unsaturated Zone** - The zone immediately below the land surface where the pores or fractures contain both water and air.

**Water Table** - The top of the water surface in the saturated zone of an unconfined aquifer.

## ACKNOWLEDGMENTS

The following individuals contributed to the development of this poster:

**Project Chief, Principal Author, and Layout:** Stephen Vandas, U.S. Geological Survey, Denver, Colorado

**Art Work:** Frank Farrar, Frank Farrar Graphics, Denver, Colorado, under contract to the American Water Resources Association

## U.S. DEPARTMENT OF THE INTERIOR

As the Nation's principal conservation agency, the U.S. Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This responsibility includes fostering the wisest use of our land and water resources, protecting our fish and wildlife, preserving the environmental and cultural values of our national parks and historical places, and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people. The Department also has a major responsibility for American Indian reservation communities and for people who live in island territories under United States administration.

GRADE SCHOOL EDITION

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## *Poster Series*

This poster is the fifth in a series of water-resources education posters developed through the Water Resources Education Initiative. The Water Resources Education Initiative is a cooperative effort between public and private education interests. Partners in the program include the U.S. Geological Survey and the U.S. Fish and Wildlife Service of the U.S. Department of the Interior, the U.S. Environmental Protection Agency, the U.S. Army Corps of Engineers, the Nebraska Groundwater Foundation, and the National Science Teachers Association.

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| **OCEANS or NAVIGATION** | **GROUND WATER** | WATER QUALITY |

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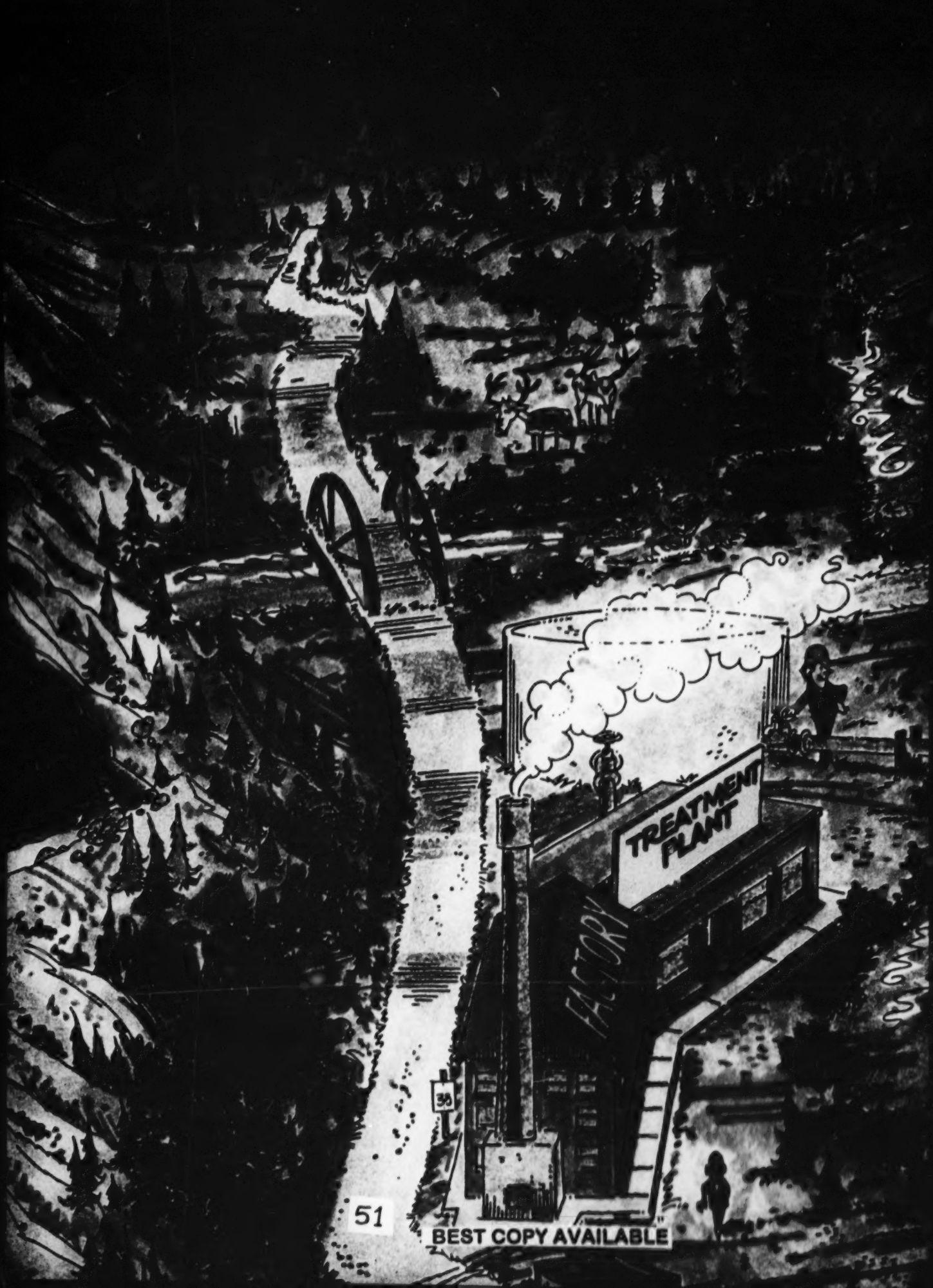




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## DEFINITIONS

**Aquifer** - An underground body of porous sand, gravel, or fractured rock filled with water and capable of supplying useful quantities of water to a well or spring.

**Erosion** - Process whereby materials of the Earth's crust are loosened, dissolved, or worn away and moved, usually by water or wind.

**Ground Water** - Water in the saturated zone beneath the Earth's surface.

**Nonpoint Source of Pollution** - Pollution from a broad area such as areas of fertilizer and pesticide application, rather than from point sources.

**Point Source of Pollution** - Pollution originating from a discrete source, such as the outflow from a pipe, ditch, tunnel, or well.

**Sediment** - Particles derived from rock or organic materials that have been transported by water or wind.

**Surface Water** - Water that is on the Earth's surface, such as rivers, streams, lakes, and reservoirs.

**Unconfined Aquifer** - An aquifer whose upper water surface (water table) is at atmospheric pressure and is free to rise and fall.

**Water Pollution** - Presence of any substance in water or addition of any substance to water that restricts the use of water.

**Water Table** - The top of the water surface in the saturated area of an aquifer.

## ACKNOWLEDGMENTS

The following individuals contributed to the development of this poster:

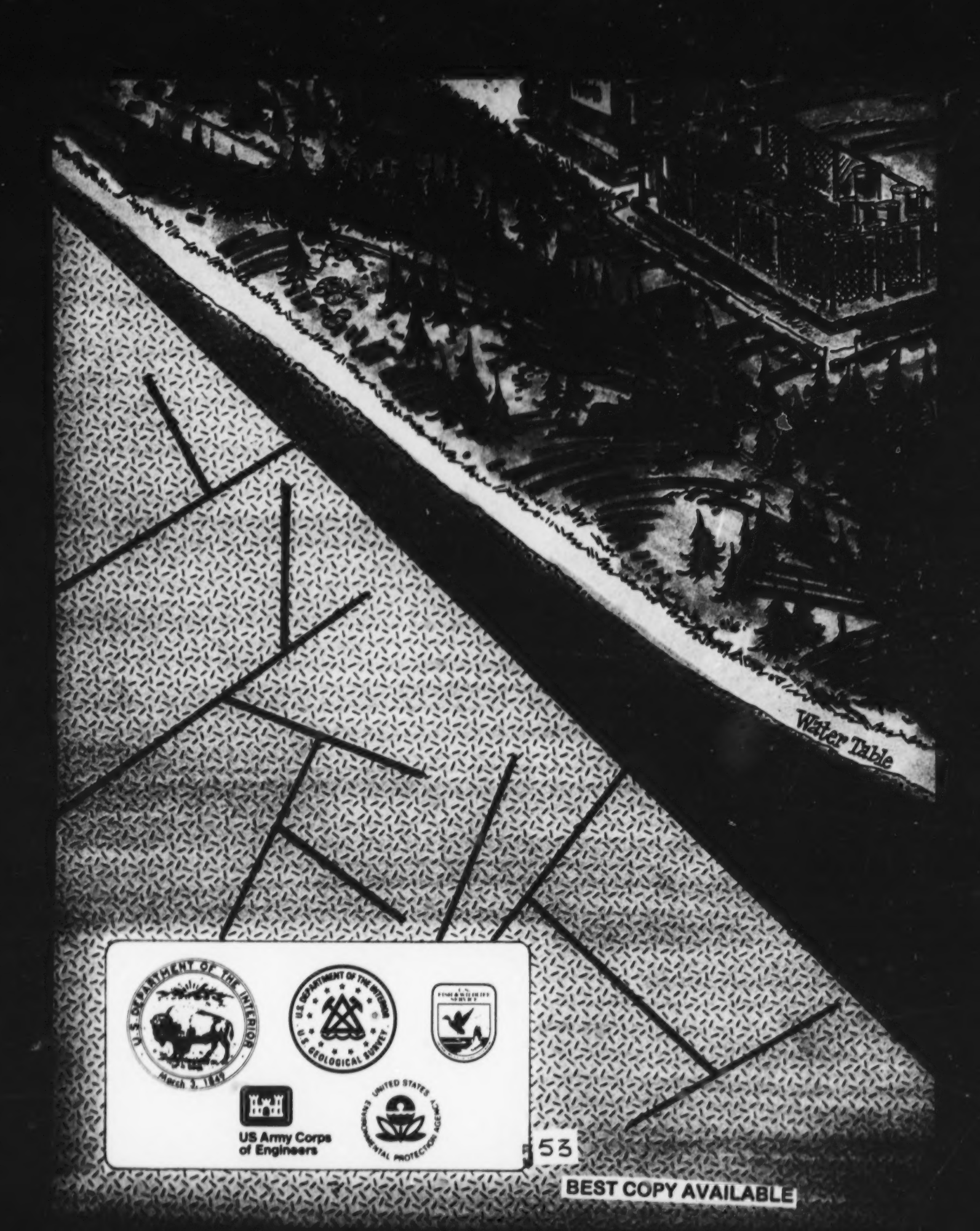
**Project Chief, Principal Author, and Layout:** Stephen Vandas, U.S. Geological Survey, Denver, Colorado

**Artwork:** Frank Farrar, Frank Farrar Graphics, Denver, Colorado, under contract to the National Science Teachers Association

## U.S. DEPARTMENT OF THE INTERIOR

As the Nation's principal conservation agency, the U.S. Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This responsibility includes fostering the wisest use of our land and water resources, protecting our fish and wildlife, preserving the environmental and cultural values of our national parks and historical places, and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people. The Department also has a major responsibility for Native American reservation communities and for people who live in island territories under United States administration.

**GRADE SCHOOL**



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# *ACTIVITY*

## *Surface-Water and Ground-Water Pollution*

### *Introduction*

Surface waters (rivers, streams, lakes, ponds) and ground waters are interconnected in some areas. That is, water can move from surface-water bodies to ground-water bodies and vice versa. If surface waters become polluted, this pollution can also affect the area's ground-water system. Likewise, polluted ground water can move into lakes, streams, or rivers. The following activity demonstrates the movement of pollutants from surface water to ground water as well as the difficulty in cleaning up the pollution.

### *Objectives* -- Students will:

1. Observe the connection between surface and ground water; and
2. Experience the difficulty of cleaning up polluted water.

### *Materials* -- Each group will need:

1. One 266-mL clear plastic cup;
2. Sufficient clean pea-sized gravel to fill the 266-mL clear plastic cup 3/4 full;
3. Three 240-mL paper cups;
4. One pump dispenser from soft-soap or hand-lotion containers;
5. 3.8 L of water; and
6. One bottle of food coloring.

### *Teacher Preparation*

1. This activity is designed for students to work in groups of three.
2. Display a copy of the poster titled "Water Quality: Potential Sources of Pollution" on the classroom wall several days prior to conducting this activity.
3. Fill a clear plastic cup 3/4 full of clean pea-sized gravel for each group.
4. Using an ice pick or awl, punch 8-10 small holes in the bottom of one of the paper cups for each group. When filled with water, this cup will be used to simulate rain.
5. Fill one paper cup (without holes) 3/4 full of water for each group.

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## Procedure

1. Divide the class into groups of three. Provide each group with one clear plastic cup 3/4 full of pea-sized gravel, one paper cup with holes in the bottom, one paper cup with no holes punched in the bottom, one paper cup 3/4 full of water, and one pump dispenser.
2. Instruct the students to hold the 240-mL cup with holes in the bottom over the cup containing the pea-sized gravel. Then add the water contained in the other 240-mL cup. Ask the students what they think the water simulates (rain).
3. Explain to the students that rain enters the gravel and becomes ground water. This process is called infiltration.
4. Instruct the students to dig a hole in the center of the gravel. Ask them what the hole simulates. (Answer: A lake or pond.) Have students observe the connection between the level of water in the lake and how it corresponds to the level of water in the gravel.
5. Add two drops of food coloring (to simulate pollution) to each model lake. Have the students place the pump dispenser in the gravel beside the lake and pump water into the paper cup with no holes. Observe the color of the water in the cup.
6. Have the students add small amounts of clean water to their models while pumping. Continue to add clean water and pump out polluted water until it becomes clear.

## Interpretive Questions

1. Where does the pollution pumped from the ground water come from?

Answer: The lake.

2. How can pollution from a lake get into the ground water?

Answer: The water in the lake and the ground water are connected.

3. Was it easy to clean up all the pollution in the water?

Answer: No. It took a lot of water and pumping to remove the pollution.

## ORDERING INFORMATION

Single copies of the first four posters in the series (see Poster Series panel) and a limited supply of the "Water Quality" poster (color for grades 3-5 and 6-8 or black and white) can be obtained at no cost from the U.S. Geological Survey by writing to the following address:

U.S. Geological Survey
Box 25286
Denver Federal Center
Denver, CO 80225
Telephone: (303) 236-7477

In your letter, please identify the poster title and grade level desired.

Also, the poster entitled "Water: The Resource That Gets Used & Used & Used for Everything!" has been translated into Spanish. A limited supply of color or black-and-white copies can be obtained at no cost from the U.S. Geological Survey at the above address.

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# *ACTIVITY*

# *Erosion*

## *Introduction*

Sediment results from the erosion of land surfaces and streambanks. One of the most effective means of controlling erosion is to protect the land surfaces and streambanks with vegetation and vegetative litter (leaves, twigs, and stems that fall from plants). Vegetation helps prevent erosion by holding soil in place. The vegetation canopy and resulting litter protect soil from the impact of rain drops, which can increase erosion. The following activity demonstrates the effectiveness of vegetative litter in preventing soil erosion.

## *Objectives* -- Student will observe:

1. The effect of rainfall on soil erosion.
2. The effect of vegetative litter on the reduction of soil erosion.

## *Materials* -- Each group will need:

1. 480 mL of soil (in two 240-mL cups);
2. One cake pan or similar container at least 30 cm x 30 cm;
3. Four 240-mL paper cups;
4. Water; and
5. A large handful of vegetative litter (leaves, twigs, grass, and stems, etc.).

## *Teacher Preparation*

1. This activity is designed for students to work in groups of three. If sufficient materials are not available, it can be done as a demonstration.
2. Using an ice pick or awl, punch 8-10 small holes in the bottom of one of the paper cups.
3. Take the students on a walk to a nearby park, woods, or field to collect soil and vegetative litter. Caution against collecting inorganic "litter" and animal waste. Also, warn students about coming in contact with poison ivy and other harmful plants.

## *Procedure*

1. Divide the class into groups of three students. Provide each group with one cake pan, one 240-mL cup with holes punched in the bottom, two 240-mL cups filled with soil, one 240-mL cup filled 2/3 full of water, and a large handful of vegetative litter.

ATER
PLANT
PARKING
LOTS
59
35

2. Have the students place one side of the cake pan on a thin book or tablet of paper to create a slight slope.
3. Have the students make a small mound with the 240 mL of soil at the upslope side of the cake pan. Explain to students that the mound represents a hill.
4. Instruct a student to hold the 240-mL cup with holes over the soil mound. Then add water to this cup. Explain to the students that they are simulating rain. Have the students observe the amount of soil in the "lake" at the bottom of the pan.

5. Introduce these words: **erosion** - the movement of soil from the mound, and **sediment** - the soil deposited in the lake at the bottom of the pan.
6. Remove the soil and water from the pan. Refill one paper cup 2/3 full of water. Repeat steps 2 and 3, using the second 240-mL cup of soil. Place the vegetative litter on top of the soil mound. Have it "rain" on the litter-covered mound as described in step 4. Have the students observe the amount of soil in the "lake" at the bottom of the pan.
7. Discuss with the students the differences between the amount of soil in the "lake" at the bottom of the pan following the two different erosion experiments.

## ***Interpretive Questions***

1. Which one of the mounds produced the greatest amount of sediment?

Answer: The mound that was not covered with vegetative litter.

2. What effect did the vegetative litter have on erosion?

Answer: It reduced the erosion by protecting the soil from direct impact of the "rain."

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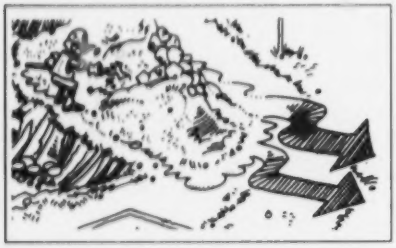
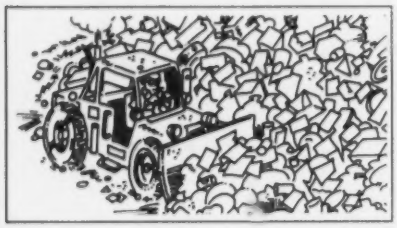
# Nonpoint-Source Pollution

Nonpoint source means that the pollution comes from a broad area, such as a large field that has been covered with fertilizer or pesticides. Excessive application of fertilizer or pesticides on agricultural lands or on lawns and gardens can create nonpoint sources. People who use fertilizers and pesticides must read labels to ensure that they are applying the materials properly.



A land-surface disturbance caused by humans, such as construction or logging, can create nonpoint sources of pollution. Pollution can occur when an increase in erosion caused by land disturbances produces large quantities of sediment, which is washed into rivers, streams, and lakes. Contamination can be reduced by preventing sediment from reaching waters through the implementation of erosion-control structures and the by planting and maintenance of soil-holding vegetation.



Disposal of garbage and trash at community landfills has the potential for polluting surface and ground water. Recycling of waste products such as oil, grease, plastics, paper, and aluminum reduces the potential for pollution from landfills. Many automobile products, such as gasoline and brake fluid, and household chemicals like cleaning solutions and turpentine, should not be placed in landfills but taken to special collection areas.

Oil and grease from automobiles, sand, gravel, salt, and other potential pollutants accumulate on parking lots and streets. Because very little water infiltrates into asphalt and concrete, the nonpoint-source pollutants that accumulate on them can be washed into surface waters during large storms. Prevention of this type of nonpoint pollution requires collection and treatment prior to discharge into surface waters.

## Hazardous Materials

Hazardous wastes produced as byproducts of manufacturing can affect water resources. Proper handling, storage, and disposal of hazardous materials is critical to the prevention of their entry into surface and ground water. This requires moving these materials to a safe storage location. What can individuals do to stop hazardous-waste pollution? One method is to stop dumping oil, cleaning liquids, or unknown substances on the ground or down the drain.

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GRADE SCHOOL EDITION

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**What is water quality? To most students, water quality may suggest only "clean" water for drinking, swimming, and fishing. But to the farmer or manufacturer, water quality may have an entirely different meaning. One of the most important issues concerning the quality of water is how that water will be used. Water that is perfectly fine for irrigation might not be suitable for drinking or swimming.**

**The quality of water can change as it flows over the land surface as rivers, streams, lakes, or ponds (surface water), or under the land surface (ground water). Because surface and ground waters are interconnected in some areas, changes in the quality of surface water can affect the quality of the area's ground water, and vice versa. These changes in water quality may be due to natural factors or human activities.**

**As rock minerals come in contact with water, some dissolve and become part of the surface- or ground-water system. Other natural materials, such as soil or organic matter, become suspended in the water and move from one place to another. The effects of human activities on water may result from land disturbances, which increase the amount of rock minerals, soils, or organic matter available to be transported by and dissolved in water, or from the addition of human-made pollutants. When water is degraded to a point that affects its use for a particular purpose, it has become polluted.**

**Water pollution originates from two very different sources: point sources and nonpoint sources. This poster depicts human activities associated with point sources (labeled in yellow) and nonpoint sources (labeled in red). Also displayed is the movement of pollutants from their sources to surface and ground waters. The stream flowing from the mountains on the left-hand side of the poster represents clean water not affected by human activities. The river on the left-hand side of the poster receives pollutants from point sources (wastewater-treatment plant, storm drain, and factory). The quantities of pollutants entering this river are reduced as a result of pollution-control measures. The river on the right-hand side of the poster receives pollutants from many nonpoint sources (suburban lawn, parking lot, construction site, landfill, logging area, septic tank, and agricultural field). This river receives large amounts of pollution because there are no pollution controls. The bottom part of the poster displays the movement of water between streams and the underlying aquifer.**

**The poster is folded into 8.5" x 11" panels; the front and back sides can easily be photocopied.**

## Point-Source Pollution

Pollution contributed to water from a discrete source, such as a pipe, ditch, tunnel, or well, are referred to as point sources. Generally, pollution from point sources are controlled to some degree by treatment technology. Municipal wastewater-treatment plants are one of the most common examples of treatment of point sources. While a municipal wastewater-treatment plant might receive water from many sources, it discharges into a water body at a single point.

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# *Poster Series*

This poster is the sixth in a series of water-resources education posters developed through the Water Resources Education Initiative. The Water Resources Education Initiative is a cooperative effort between public and private education interests. Partners in the program include the U.S. Geological Survey and the U.S. Fish and Wildlife Service of the U.S. Department of the Interior, the U.S. Environmental Protection Agency, the U.S. Army Corps of Engineers, the Nebraska Groundwater Foundation, and the National Science Teachers Association.

The other completed posters in the series are entitled "Water: The Resource That Gets Used & Used & Used for Everything!", "How Do We Treat Our Wastewater?", "Wetlands: Water, Wildlife, Plants, & People!", "Ground Water: The Hidden Resource!", and "Water Quality: Potential Sources of Pollution." The posters in the series are designed to be joined to create a wall mural. A schematic of the wall mural including the topics for the completed and planned posters is displayed on this panel. The light-shaded spaces indicate the completed posters. The dark-shaded space represents this poster.

| | | |
|---|---|---|
| **BIODIVERSITY** | **WATERSHEDS** | **ACID RAIN or HAZARDOUS MATERIAL** |
| **WETLANDS** | **WATER USE** | **WASTEWATER TREATMENT** |
| OCEANS or NAVIGATION | **GROUND WATER** | **WATER QUALITY** |

Water-resources topics are drawn in a cartoon format by the same artist. Posters are available in color or black and white. The reverse side of the color posters contain educational activities: one version for children in grades 3–5 and the other with activities for children in grades 6–8. The black-and-white posters are intended for coloring by children in grades K–2.

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## ORDERING INFORMATION

Copies of the first five posters in the series (see Poster Series panel) and the Navigation poster (color for grades 3–5 and 6–8 or black and white) can be obtained at no cost from the U.S. Geological Survey. Write to the address below and specify the poster title(s) and grade level(s) desired. A limited number of color and black-and-white posters entitled "Water: The Resource That Gets Used & Used & Used for Everything!" are also available in Spanish by writing to the address below.

U.S. Geological Survey
Box 25286
Denver Federal Center
Denver, CO 80225
Telephone: (303) 236-7477

## ACKNOWLEDGMENTS

The NAVIGATION poster was sponsored by the U.S. Army Corps of Engineers Water Resources Support Center, Institute for Water Resources (WRSC-IWR), Alexandria, VA. Significant contributions were made by staff from the IWR and the Navigation Data Center.

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**Project Chief, Water Resources Education Initiative:**
Stephen Vandas, U.S. Geological Survey, Denver, CO

**Art Work:** Frank Farrar, Frank Farrar Graphics, Denver, CO

## U.S. ARMY CORPS of ENGINEERS

The U.S. Army Corps of Engineers is responsible for the operation and maintenance of the Nation's waterways to ensure efficient and safe passage of commercial and recreational vessels. The Corps' navigation projects play an integral role in the Nation's economy by providing efficient means by which commercial shippers can economically transport foreign and domestic products.

## U.S. DEPARTMENT of the INTERIOR

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**GRADE SCHOOL**

GRADE SCHOOL EDITION

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# ACTIVITY
# Comparing Different Modes of Transportation

## Introduction

Transportation of domestic cargo by barge is relatively slow, but it is efficient and cost effective for moving large amounts of goods from one place to another. A comparison of the cargo capacities of a barge, jumbo hopper rail car, and large semitrailer truck is shown below.

BARGE
1500 TON
52,500 BUSHELS
453,600 GALLONS

JUMBO HOPPER CAR
100 TON
3,500 BUSHELS
30,240 GALLONS

LARGE SEMI
26 TON
910 BUSHELS
7,865 GALLONS

## Objective -- Students will:

Compare cargo capacities of barges, trains, and trucks.

## Materials

1. 174 small objects such as blocks, marbles, or beads that can be carried easily by students.
2. Shoe box.

## Teacher Preparation

1. Display the poster "Navigation: Traveling the Water Highways" several days before conducting this activity.
2. Divide the small objects into three groups of 58 each. Place one group of 58 objects in the shoe box for easy carrying. The shoe box represents the carrying capacity of a barge. Each object represents 26 tons of coal.

## Procedure

1. Place the two groups of 58 objects and the shoe box (containing 58 objects) separately at one end of a room.
2. Select three students for participation in this activity. One student will represent a barge, the second student a jumbo hopper rail car, and the third student a large semitrailer truck. These students will carry the objects from one side of the room to the other.
3. Explain to the students that the barge, rail car, and truck will carry different numbers of objects across the room, depending on how much cargo each is able to carry on one trip. The student who represents the truck will carry only one object on each trip across the room. The student who represents the rail car will carry four objects per trip across the room. The student representing the barge will carry the shoe box containing all 58 objects in one trip. Each of the three students (representing different modes of transportation) should cross the room as many times as necessary to carry all 58 objects from one end of the room to the other.

## Interpretive Questions

1. How many times did the truck have to cross the room to move all 58 objects? (Answer: 58); the rail car? (Answer: 15); the barge? (Answer: 1).
2. Does the barge, rail car, or truck carry the most cargo? (Answer: barge).

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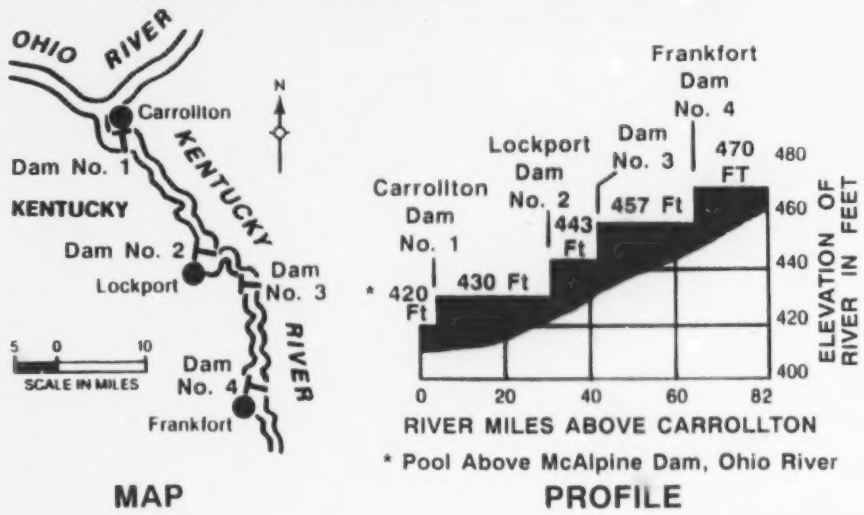
sketch of its river profile. Compare the similarities and differences between the groups' river profiles.

## Extension

1. Below is a map showing sections of the Kentucky and Ohio Rivers. The profile shows the elevations of the navigation pools along the Kentucky River south of its confluence (joining) with the Ohio. Have the students determine the difference in elevation between each pair of adjacent dams. (Answers: 1 & 2 - 13 ft.; 2 & 3 - 14 ft.; 3 & 4 - 13 ft.)

**KENTUCKY RIVER MAP AND PROFILE**




**MAP** **PROFILE**

## DEFINITIONS

**Barge** - Long, unpowered, flat-bottomed boat used to transport cargo on water; pushed or pulled by a powered boat.

**Dam** - Barrier built across a river to create a pool of water for navigation, flood control, water supply, or power generation.

**Domestic** - Within the United States.

**Dredge** - Machine equipped with a scooping or suction device used in deepening and widening harbors and waterways.

**Harbor** - Sheltered part of a water body deep enough to provide anchorage for ships or boats.

**Lock** - Walled navigational structure to allow raising or lowering vessels from one water level to another.

**Locking through** - Using a navigation lock to "step" up or down on a river.

**Port** - Region or city having a natural or artificial harbor with equipment, facilities, warehouses, and berths for ships taking on or discharging cargo or passengers.

**Sediment** - Solid material (gravel, sand, and silt) that settles to the bottom of a river.

**Towboat** - Powerful boat with a flat bottom and flat front used to push barges on rivers and other calm waterways.

**Tugboat** - Powerful boat with V-shaped bottom and rounded front used to pull barges on open water or maneuver ships in ports.

**Vessel** - Boat or ship intended for navigation on water.

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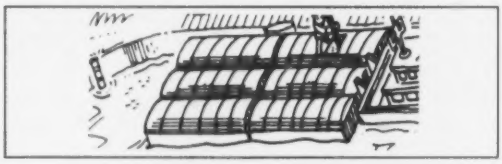
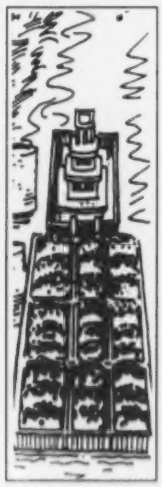
# River Vessels:

The most common way of transporting products on rivers is by TOW. A tow consists of one TOWBOAT and one or more BARGEs. Towboats push different kinds of barges, depending on the cargo. Three of the four basic types of barges are shown below. The fourth type is a DECK barge, which carries almost any kind of equipment, materials, or products that can be tied down and do not need protection from the weather.

COVERED DRY CARGO barge: Carries bulky solid cargo, such as dry cement, fertilizer, and farm products (corn, wheat, and soybeans) that need protection from the weather.





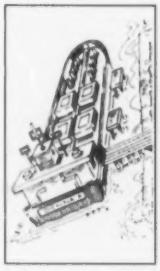
OPEN HOPPER barge: Holds bulky products, such as sand, gravel, or coal, that do not need protection from the weather.

LIQUID CARGO (TANK) barge: Transports liquid products such as chemicals, petroleum, oil, and molasses.

# Ocean-Going Vessels:

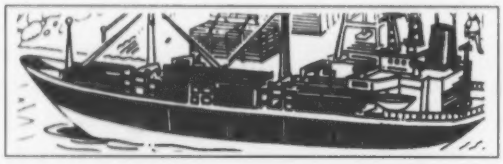
Many products are traded with other countries by using deep-water ocean ports. Products that come into the country are called imports and those that are shipped to other countries are called exports. Trucks, trains, tows, and pipelines transport products into and out of ocean ports. Some of the large, ocean-going vessels in the deep-water harbor are shown below.

CONTAINERSHIP: Transports products stored in 20- to 45-foot-long containers that are stacked inside the ship and outside on the deck. Some ships carry as many as 5,000 containers.



TANKER ship: Holds chemicals, petroleum products, oil, and other liquids.

BREAK BULK ship: Carries bulky cargo such as lumber, packages of fertilizer, and boxes of fruit. Break bulk cargo is usually loaded and unloaded on portable platforms ("pallets").



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# ACTIVITY
# River Profile

## Introduction

Locks and dams are necessary structures for safe travel on rivers with shallow water. The upper part of the Mississippi River (north of St. Louis, Missouri) is controlled by 29 dams. Tows and other vessels use locks to navigate around the dams. In this activity, the students use building blocks to simulate elevation changes in a river with dams. A map (aerial) view of the river is compared with the profile, or cross section, of the same stretch of river. A river's profile shows the river surface and bottom, dams, and navigation pools.

## Objective -- Students will:

Learn to correlate a river's map view with its side view (profile).

## Materials

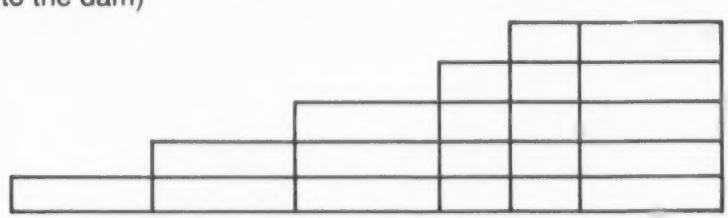
1. For each group of students and the instructor: 20 rectangular wooden blocks (11 of the blocks should be twice as long as the other 9).
2. Pencil and paper.

## Teacher Preparation

1. Display the poster "Navigation: Traveling the Water Highways" several days before conducting this activity.
2. Discuss the importance of locks and dams. Explain the locking through process with the class (see adjacent panel).
3. Divide the students into groups of 3. Separate blocks into sets of 11 long and 9 short blocks for each group and the instructor.

## Procedure

1. Instructor: Use the cross-sectional diagram (profile) of the river below to "build" a river channel with four dams out of wooden blocks. Ask the students to observe while the river is built and discuss the four obstacles (dams) that a coal tow would encounter on this river. Explain that the tow must "step" up or down the river where the dams are located. Ask the students to show you where the locks should be constructed. (Answer: parallel to the navigation pool and perpendicular to the dam)



2. When the river model is finished, ask the students to look at the blocks from the top. Explain to them that they are looking at a map or aerial view of the river. Have the students look at the river from the side. Explain that they are now looking at a profile, or cross section, of the river.
3. Hand out blocks to each group. Ask each group of students to build a river model. Challenge the students to design and construct their own river models. Have each group draw a rough

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**NAVIGATION** is travel or transportation over water. Many different kinds of boats and ships are used on rivers and oceans to move people and products from one place to another.

Navigation was extremely important for foreign and domestic trade and travel in the early days of our country before cars, trucks, trains, and airplanes were invented. In those days, rivers were used as "roads" to connect inland settlements to river and coastal ports. Communities established at these commercial ports became important economic, cultural, and social hubs in the development of our Nation.

Many of the products we use and eat today are still transported by vessels on deep oceans and relatively shallow rivers or inland waterways. Towboats push barges (labeled in red) loaded with products such as grain, coal, and petroleum up and down rivers to loading and unloading facilities. Activities at a deep-water coastal port might include the loading or unloading of large commercial ocean-going vessels with lumber, oil, or cargo in large containers. Ocean-going vessels (labeled in yellow) maneuver in deep coastal harbors with the help of tugboats.

Navigation activities in the United States take place at more than 400 ports and along more than 25,000 miles of waterways. Some of the ports and waterways making up the extensive navigation network in this country are shown on the map below. Most rivers in the western part of the United States are not used for commercial navigation. Some of these rivers are used instead for recreation, irrigation, and generation of electricity. Shallow harbors or rivers are made safe for navigation by dredging or the construction of locks and dams.

## Ports and Navigable Waterways of the United States

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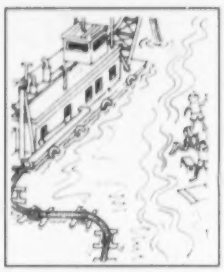
# Dredging:

Sediment (gravel, sand, and silt) is deposited naturally in a harbor or river channel when a river slows down. Accumulated sediment reduces the channel depth and can make the waterway unsafe for navigation. Mechanical and hydraulic dredges are used to deepen and widen channels filled with sediment and deposit the sediment in an approved location. Mechanical dredges shovel or scoop up bottom materials and place them on a barge or scow. The two hydraulic dredges shown on this poster use pumps to remove a mixture of water and sediment ("slurry") from the channel bottom. The HOPPER DREDGE is an ocean-going vessel used to dredge sediment from the bottom of a deep-water channel or coastal harbor. Dredged material is stored in "hopper bins" inside the ship before disposal in the open sea or other location.

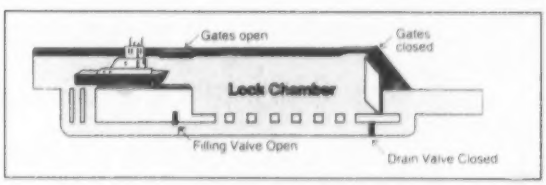


PIPELINE DREDGE: Vessel commonly used to dredge sediment from the bottom of shallow rivers or calm coastal waters. Dredged material is pumped from the river or ocean bottom and flows through a floating pipeline to shore. The dredged material commonly is used to restore eroded beaches.

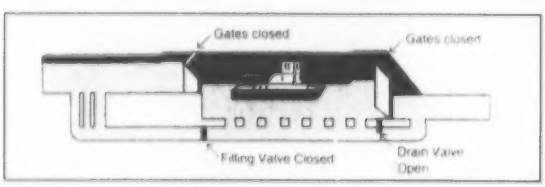
# Locks and Dams:

Dams are built on shallow rivers to hold back water and form deeper navigation "pools." Most pools in the United States are maintained at a constant minimum water depth of 9 feet for safe navigation. Dams make it necessary for river vessels to use a series of locks to "step" up or down the river from one water level to another. The three steps in the "LOCKING THROUGH" process are shown below.

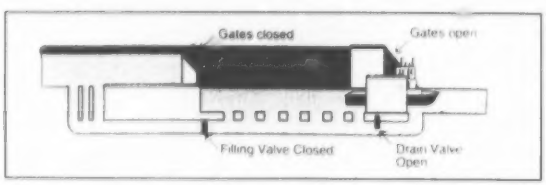
For a boat going downstream, the lock is first filled by opening the filling valve. The drain valve and upstream and downstream gates are closed, so the level of the water in the chamber rises to the upstream level. The upstream gate opens and the boat moves in.




To lower the boat, the gates are closed behind it, the filling valve is closed, and the drain valve is opened. The higher water in the lock chamber drains to the downstream level within minutes.




The downstream gate is then opened and the boat moves out on the lower water level. The process is reversed for a boat going upstream.



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81

US Army Corps
of Engineers

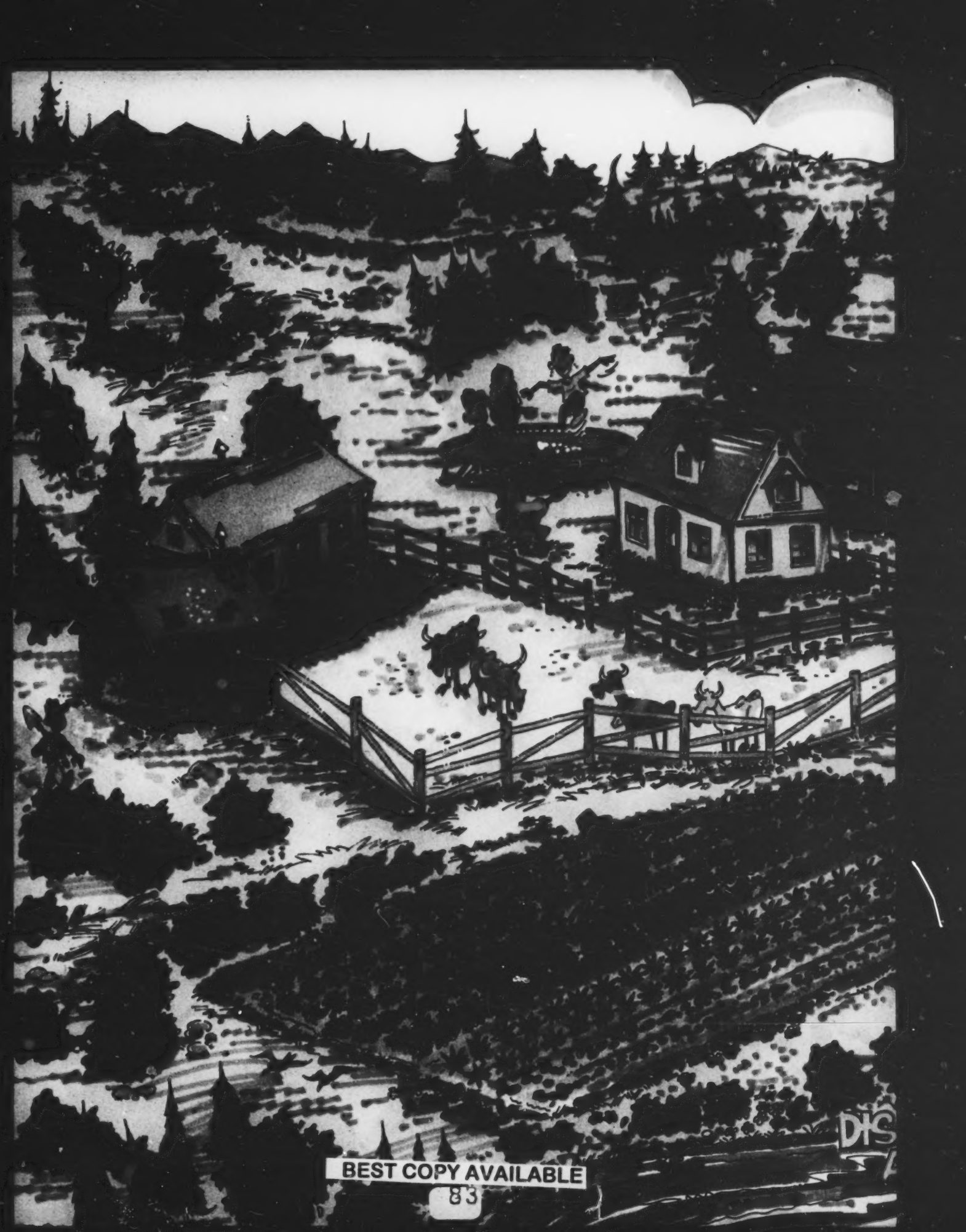
## *Poster Series*

This poster is the fourth in a series of water-resources education posters developed through the Water Resources Education Initiative. The Water Resources Education Initiative is a cooperative effort between public and private education interests. Partners in the program include the U.S. Geological Survey and U.S. Fish and Wildlife Service of the U.S. Department of the Interior, the U.S. Environmental Protection Agency, the American Water Resources Association, the Nebraska Groundwater Foundation, and the National Science Teachers Association.

The first completed poster in the series is entitled "Water: The Resource That Gets Used & Used & Used for Everything!" The second and third posters in the series are entitled "How Do We Treat Our Wastewater?" and "Wetlands: Water, Wildlife, Plants & People!" The posters in the series are designed to be joined together to create a wall mural. A schematic of the wall mural including the topics for the completed and planned posters is displayed on this panel. The lightly shaded spaces indicate the completed posters. The dark-shaded space is this poster.

| | | |
|---|---|---|
| **ICE/GLACIER or WATERSHEDS** | **HYDROLOGIC CYCLE** | **ACID RAIN or HAZARDOUS MATERIAL** |
| **WETLANDS** | **WATER USE** | **WASTEWATER TREATMENT** |
| **OCEANS or NAVIGATION** | GROUND WATER | **WATER QUALITY** |

Water-resources topics of the completed posters are drawn in a cartoon format by the same cartoonist. Posters are available in color or black and white. The reverse side of the color posters contain educational activities: one version for children in grades 3-5 and the other with activities for children in grades 6-8. The black-and-white posters are intended for coloring by children in grades K-2.



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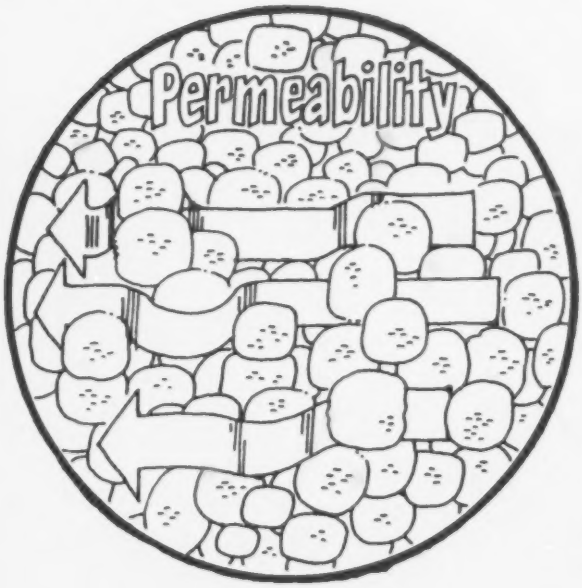
Ground water is water underground in saturated zones beneath the land surface. Contrary to popular belief, ground water does not form underground "rivers." It fills the pores and fractures in underground materials such as sand, gravel, and other rock. If ground water flows from rock materials or can be removed by pumping from the saturated rock materials in useful amounts, the rock materials are called aquifers. Ground water moves slowly, typically at rates of 7 to 60 centimeters per day in an aquifer. As a result, water could remain in an aquifer for hundreds or thousands of years. Ground water is the source of about 40 percent of water used for public supplies and about 38 percent of water used for agriculture in the United States.

One of the largest aquifers in the United States is the High Plains Aquifer. The aquifer is approximately the size of California and is located under parts of South Dakota, Wyoming, Kansas, Nebraska, Colorado, New Mexico, Oklahoma, and Texas. The High Plains Aquifer contains an estimated 4 quadrillion liters (4 with 15 zeros after it) of water.

This poster depicts an unconfined or water-table aquifer. An unconfined aquifer is an aquifer where the water surface — water table — is free to rise and decline as water moves from recharge areas to discharge areas. Recharge areas are places where an aquifer receives its water. The recharge sources shown are a reservoir, a stream, and precipitation. Their titles are red. The arrows represent the movement of water from the recharge sources to the discharge areas. The large circle on the right-hand side of the poster is a representation of how recharge occurs from precipitation.

The left-hand side of the poster shows conditions in a ground-water discharge area. Discharge areas are where ground water flows to the land surface or to surface-water bodies such as the pond and river shown on the poster. Ground water also can discharge by pumping a well. The titles of these ground-water discharges are yellow.

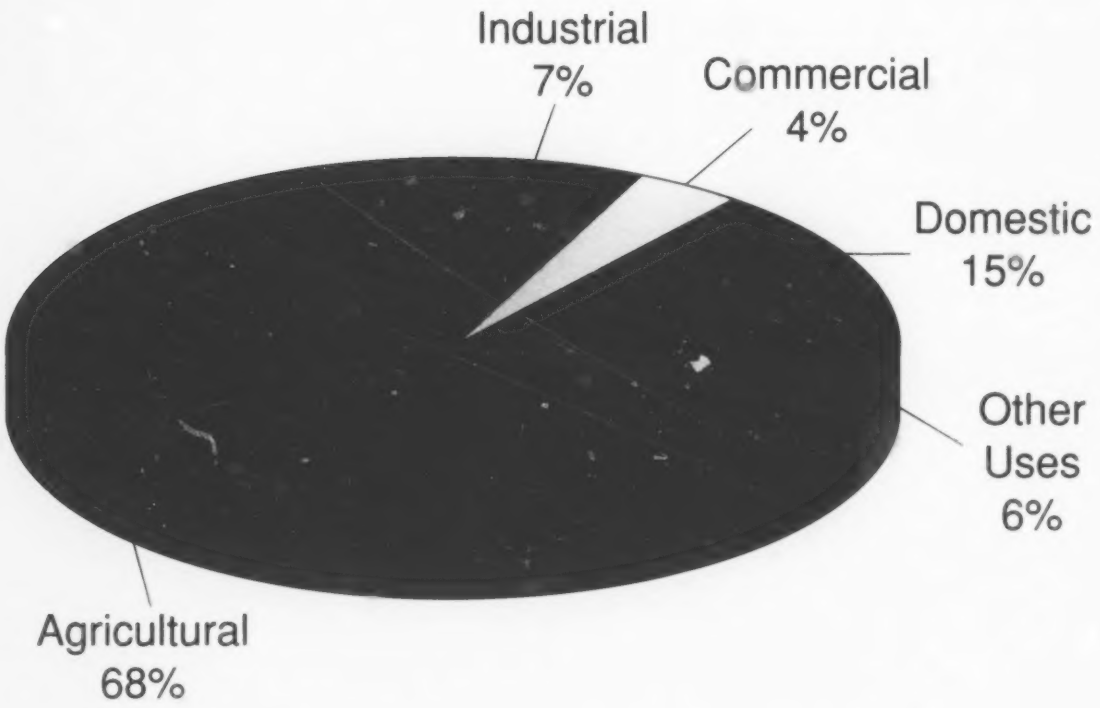
The poster is folded into 8.5" x 11" panels; front and back panels can easily be photocopied.




## Permeability

For water to move in an aquifer, the pores between rock materials and fractures in rock must be connected. If there is a good connection among pore spaces and fractures, water can move freely and we say that the rock is permeable. The capacity of rock material to transmit water is called permeability. Water moves through different materials at different rates — faster through gravel, slower through sand, and much slower through clay. Therefore, gravel is more permeable than sand, which is more permeable than clay.

# *HOW GROUND-WATER IS USED IN THE UNITED STATES*




Total ground-water use in 1990, was 301,000 million liters per day.

Nationally, the largest use of ground water is Agricultural, followed by Domestic, Industrial, and Other Uses. Agricultural use includes ground water for irrigating crops and watering livestock. The Other Uses category includes ground-water use for mining and thermoelectric power. Only freshwater use is considered for this pie chart.

How does your State's ground-water use compare to the national uses identified in the pie chart?

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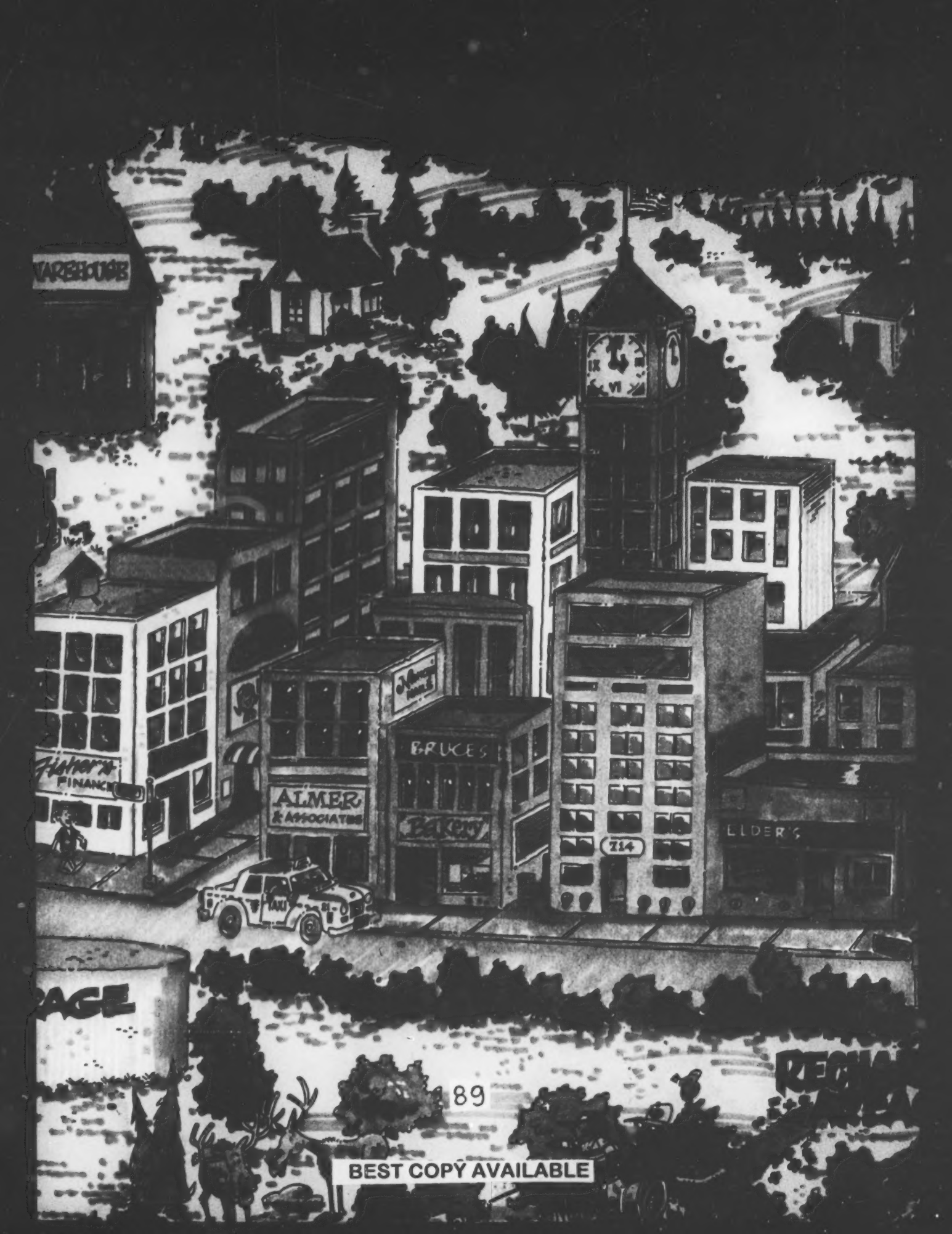
# GROUND-WATER USE FOR THE UNITED STATES, 1990

## (in million liters per day)

| STATE | NATIONAL RANK | DOM-ESTIC | COM-MERCIAL | INDUS-TRIAL | AGRI-CULTURE | OTHER | TOTAL |
|---|---|---|---|---|---|---|---|
| Alabama | 35 | 546.0 | 81.0 | 340.0 | 395.0 | 129.0 | 1,490.0 |
| Alaska | 49 | 65.0 | 80.0 | 45.0 | 0.6 | 51.0 | 240.0 |
| Arizona | 9 | 1,210.0 | 319.0 | 317.0 | 7,880.0 | 644.0 | 10,400.0 |
| Arkansas | 5 | 467.0 | 209.0 | 375.0 | 16,700.0 | 35.0 | 17,800.0 |
| California | 1 | 8,730.0 | 1,890.0 | 1,520.0 | 41,200.0 | 1,770.0 | 55,200.0 |
| Colorado | 8 | 285.0 | 81.0 | 134.0 | 9,760.0 | 223.0 | 10,500.0 |
| Connecticut | 43 | 313.0 | 104.0 | 118.0 | 35.0 | 55.0 | 625.0 |
| Delaware | 46 | 102.0 | 33.0 | 89.0 | 94.0 | 18.0 | 337.0 |
| District of Columbia | 53 | 0.0 | 0.0 | 1.9 | 0.0 | 1.9 | 3.8 |
| Florida | 6 | 5,300.0 | 1,130.0 | 1,680.0 | 7,620.0 | 1,930.0 | 17,700.0 |
| Georgia | 16 | 922.0 | 253.0 | 1,450.0 | 1,030.0 | 109.0 | 3,770.0 |
| Hawaii | 29 | 475.0 | 367.0 | 103.0 | 770.0 | 516.0 | 2,230.0 |
| Idaho | 2 | 648.0 | 81.0 | 655.0 | 27,200.0 | 182.0 | 28,700.0 |
| Illinois | 18 | 1,250.0 | 656.0 | 824.0 | 512.0 | 238.0 | 3,480.0 |
| Indiana | 28 | 967.0 | 298.0 | 670.0 | 172.0 | 242.0 | 2,650.0 |
| Iowa | 32 | 552.0 | 234.0 | 362.0 | 424.0 | 301.0 | 1,870.0 |
| Kansas | 7 | 437.0 | 160.0 | 250.0 | 15,400.0 | 267.0 | 16,500.0 |
| Kentucky | 40 | 277.0 | 27.0 | 448.0 | 7.7 | 177.0 | 936.0 |
| Louisiana | 13 | 943.0 | 136.0 | 1,150.0 | 2,550.0 | 295.0 | 5,070.0 |
| Maine | 47 | 213.0 | 31.0 | 49.0 | 2.8 | 27.0 | 323.0 |
| Maryland | 41 | 413.0 | 105.0 | 99.0 | 120.0 | 173.0 | 909.0 |
| Massachusetts | 37 | 485.0 | 264.0 | 349.0 | 5.2 | 176.0 | 1,280.0 |
| Michigan | 25 | 877.0 | 271.0 | 954.0 | 467.0 | 91.0 | 2,660.0 |
| Minnesota | 21 | 1,560.0 | 257.0 | 338.0 | 809.0 | 53.0 | 3,020.0 |
| Mississippi | 10 | 913.0 | 168.0 | 606.0 | 8,150.0 | 282.0 | 10,100.0 |
| Missouri | 24 | 592.0 | 144.0 | 339.0 | 1,320.0 | 358.0 | 2,750.0 |
| Montana | 42 | 168.0 | 35.0 | 113.0 | 403.0 | 57.0 | 776.0 |
| Nebraska | 4 | 587.0 | 149.0 | 244.0 | 16,900.0 | 262.0 | 18,100.0 |
| Nevada | 14 | 280.0 | 118.0 | 38.0 | 3,300.0 | 272.0 | 4,010.0 |
| New Hampshire | 48 | 169.0 | 24.0 | 22.0 | 3.1 | 23.0 | 241.0 |
| New Jersey | 30 | 996.0 | 260.0 | 548.0 | 92.0 | 246.0 | 2,140.0 |
| New Mexico | 11 | 637.0 | 289.0 | 66.0 | 5,260.0 | 418.0 | 6,670.0 |
| New York | 20 | 1,800.0 | 390.0 | 547.0 | 165.0 | 270.0 | 3,180.0 |
| North Carolina | 34 | 595.0 | 153.0 | 395.0 | 180.0 | 323.0 | 1,650.0 |
| North Dakota | 45 | 111.0 | 25.0 | 12.0 | 347.0 | 38.0 | 533.0 |
| Ohio | 19 | 1,020.0 | 470.0 | 841.0 | 47.0 | 1,040.0 | 3,420.0 |
| Oklahoma | 27 | 290.0 | 77.0 | 79.0 | 2,000.0 | 60.0 | 2,500.0 |
| Oregon | 22 | 423.0 | 84.0 | 184.0 | 2,140.0 | 67.0 | 2,900.0 |
| Pennsylvania | 15 | 1,070.0 | 245.0 | 915.0 | 188.0 | 1,460.0 | 3,870.0 |
| Puerto Rico | 44 | 134.0 | 42.0 | 51.0 | 221.0 | 147.0 | 595.0 |
| Rhode Island | 51 | 49.0 | 27.0 | 16.0 | 1.6 | 2.2 | 96.0 |
| South Carolina | 38 | 525.0 | 109.0 | 217.0 | 160.0 | 58.0 | 1,070.0 |
| South Dakota | 39 | 149.0 | 87.0 | 39.0 | 599.0 | 76.0 | 949.0 |
| Tennessee | 31 | 719.0 | 472.0 | 415.0 | 166.0 | 134.0 | 1,910.0 |
| Texas | 3 | 3,920.0 | 377.0 | 935.0 | 21,500.0 | 1,190.0 | 28,000.0 |
| Utah | 17 | 835.0 | 157.0 | 342.0 | 2,030.0 | 288.0 | 3,650.0 |
| Vermont | 50 | 113.0 | 17.0 | 9.7 | 17.0 | 14.0 | 170.0 |
| Virgin Islands | 52 | 1.2 | 2.6 | 0.3 | 1.2 | 2.0 | 7.2 |
| Virginia | 33 | 556.0 | 165.0 | 793.0 | 62.0 | 99.0 | 1,680.0 |
| Washington | 12 | 1,420.0 | 326.0 | 569.0 | 2,940.0 | 244.0 | 5,490.0 |
| West Virginia | 23 | 269.0 | 30.0 | 412.0 | 4.8 | 2,040.0 | 2,750.0 |
| Wisconsin | 26 | 676.0 | 228.0 | 504.0 | 848.0 | 322.0 | 2,580.0 |
| Wyoming | 36 | 129.0 | 32.0 | 32.0 | 950.0 | 309.0 | 1,450.0 |
| TOTAL | | 46,200.0 | 11,800.0 | 21,600.0 | 203,000.0 | 17,800.0 | 301,000.0 |

Use might not add to TOTALS because of independent rounding.
Category explanation located under pie chart.



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# ACTIVITY
# Recharge - Discharge

## Introduction

Recharge is the addition of water to an aquifer. Recharge can occur from precipitation or from surface-water bodies such as lakes or streams. Water is lost from an aquifer through discharge. Water can be discharged from an aquifer through wells and springs, and to surface-water bodies such as rivers, ponds, and wetlands. The following activity is designed to demonstrate the recharge and discharge of water to a model aquifer.

## Objectives--Students will:

1. Identify several sources of recharge for ground water.
2. Identify several sources of discharge for ground water.
3. Discuss how water moves from recharge to discharge areas.
4. Discuss the connection between surface water and ground water.

## Materials

1. One clear container at least 15-cm wide x 22-cm long x 6-cm deep for each group. Possible containers include clear plastic salad containers or clear baking pans.
2. Sufficient pea-size gravel to fill the container approximately 2/3 full.
3. Two 472-mL paper cups for each group.
4. One pump dispenser from soft-soap or hand-lotion containers for each group.
5. 472 mL of water.
6. Grease pencils, one for each group.
7. Twigs or small tree branches, to represent trees on the model (optional).
8. Colored powdered-drink mix or food coloring (optional).

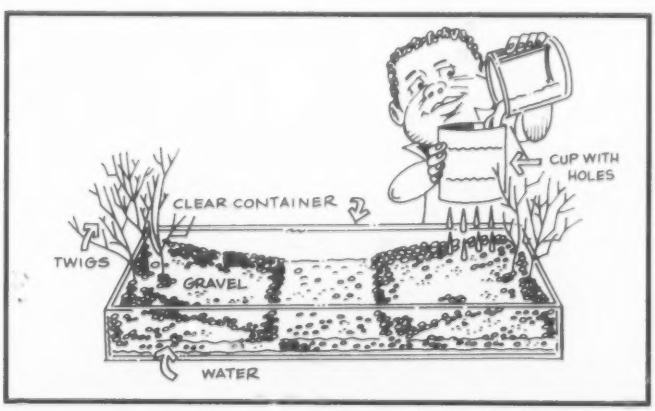
## Teacher Preparation

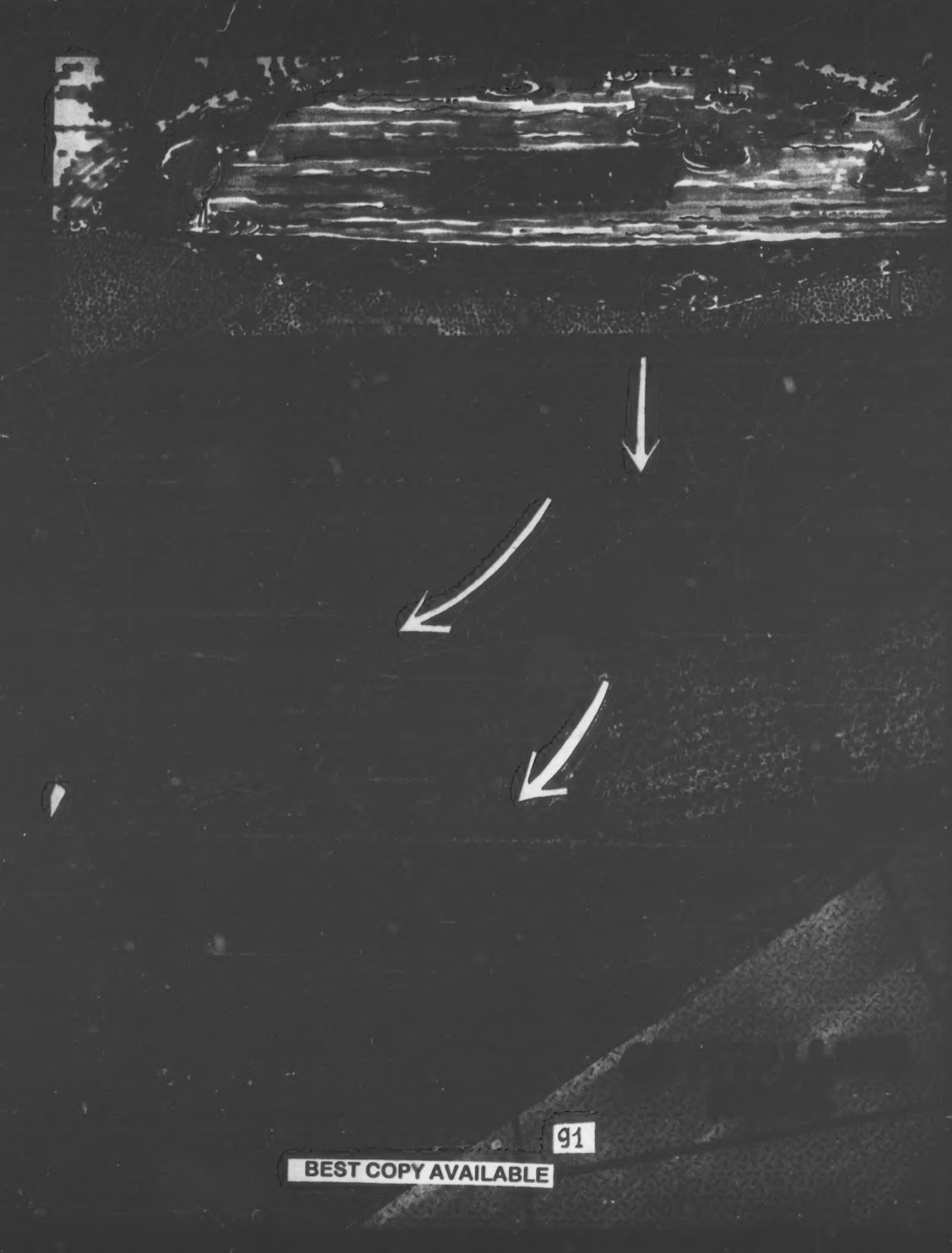
1. Display a copy of the poster titled "Ground Water: The Hidden Resource" on the classroom wall several days prior to conducting this activity.
2. Using an ice pick or awl, punch 8 to 10 small holes in the bottom of one of the paper cups. When filled with water, this cup will be used to simulate rain.
3. Fill the clear containers 2/3 full with pea-size gravel.

## Procedure

- Divide the class into small groups. Provide each group with one clear container filled 2/3 with pea-size gravel, one 472-mL cup with holes punched in the bottom, one 472-mL cup with no holes, and one pump dispenser.

- Students make models to represent hills and a valley. One student from each group fills the 472-mL cup without holes in the bottom with water. Each group makes a valley in the center of the model by pushing gravel to the farthest opposite ends of the container so the valley extends completely across the width of the container. About 2 cm of pea-sized gravel remains in the bottom of the valley.







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- Explain to the students that the gravel mounds on both sides of the container represent hills with a valley in between. The students can place twigs or small branches on the hills to represent trees. Instruct a student to hold the 472-mL cup with holes over the model. Then add 472 mL of water to this cup. Tell the students that they are simulating rain. Have the students observe how the water infiltrates into the gravel and becomes ground water.

- Introduce the word recharge — the addition of water to the ground-water system. Observe that water is standing in the valley. Have the students use a grease pencil to draw a line identifying the water level in the container. The line should traverse the entire model, identifying the water level under the hills and in the valley. There will be a pond in the valley.

- Explain that they have just identified the top of the ground water in their model. The top of the ground water is called the water table. Discuss with the students how the ground water becomes a pond in the valley. This is because the water table is higher than the land surface (gravel) in the valley.

- Have the students insert the pump into one of the hills on the side of the valley, pushing the bottom down to the ground water. Allow each of the students in the group to press the pump 20-30 times after the water in the pump has begun to flow. Catch the water in the paper cup with no holes in the bottom. After each student takes a turn pumping, instruct them to observe the location of the water table in relation to the grease-pencil line. Where did the water go? What happened to the pond? Discuss discharge, the removal of water from the ground. Discuss the effect of ground-water pumping on streams and lakes.

## ***Interpretive Questions***

1. Where does ground water come from?

**Answer:** Precipitation (rain, snow, sleet, etc.) Also, if the water table is at or below the surface of the water in a stream or pond, water can move from the stream or pond to recharge the ground-water system.

2. What would happen in the students' neighborhood (name a local stream or pond) if a well was drilled near that stream or pond and enough water pumped to lower the water table around the stream or pond?

**Answer:** Some water from the stream or pond would be removed by the pump through the well. If enough water is removed, a pond or small stream could go dry.

## ***Extension***

Sprinkle a colored powdered-drink mix or food coloring on top of one of the hills and repeat the above activity by having it rain on the model. Discuss the movement of "pollution" from the hill to the ground water to the lake.

## ***ORDERING INFORMATION***

Single copies of the first three posters in the series (see Poster Series panel) and a limited supply of the "Ground Water" poster (color for grades 3-5 and 6-8 or black and white) can be obtained at no cost from the U.S. Geological Survey.

U.S. Geological Survey
Box 25286
Denver Federal Center
Denver, CO 80225
Telephone: (303) 236-7477

Also, the poster entitled "Water: The Resource That Gets Used & Used & Used for Everything!" has been translated into Spanish. A limited supply of color or black-and-white copies can be obtained at no cost from the U.S. Geological Survey at the above address.

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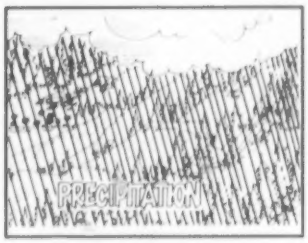
# Recharge Areas



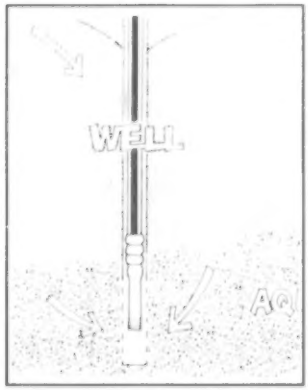

Recharge is the addition of water to the ground-water system. The recharge of freshwater begins as precipitation. Precipitation occurs in several forms, including rain, snow, and hail, but only rain is displayed on the poster. Some of the rain infiltrates into the soil. If the rate of the rainfall exceeds the rate of infiltration, surface water will flow over the land surface to surface-water bodies such as rivers and streams.

Water can infiltrate faster from the land surface into sandy soils than silty or clay soils. Water infiltrates into the soil and the unsaturated zone. The unsaturated zone occurs immediately below the land surface and contains both water and air in the pores and fractures in the rock materials. Water moves, or percolates, down through the unsaturated zone to the saturated zone. The saturated zone is where all the pores or fractures in rock materials are filled with water. The top of the saturated zone is called the water table.

Because surface-water and ground-water systems are connected, surface water can recharge ground water. Aquifers can obtain water from such surface-water bodies as reservoirs and streams when and where the water table is lower than the surface-water body. Recharge areas usually are higher in elevation than discharge areas.

# Discharge Areas

Places where ground water flows from aquifers to springs, seeps, wetlands, ponds, or streams are called ground-water discharge areas. Ground-water discharge to these natural areas occurs when the water surface of the aquifer (water table on the poster) is at or above the elevation of the discharge area (river and pond on the poster). Surface-water and ground-water systems are interconnected. The flow of most streams is sustained by ground water seeping into the stream. The water surfaces of many ponds and wetlands are an extension of the local ground-water table. Springs occur where ground water flows from an aquifer to the land surface.




Ground water can be brought to the land surface by pumping from a well. A well is an opening that has been drilled or dug into an aquifer below the water table. Water from the aquifer flows into this opening to replace water removed by pumping water from the well. The water table slopes from areas of recharge to discharge areas like rivers, ponds, wells, and springs.

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U.S. DEPARTMENT OF THE INTERIOR
March 3, 1849

U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

95

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US Army Corps of Engineers

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

Supplies of the first three posters may be purchased from:

American Water Resources Association
5410 Grosvenor Lane, Suite 220
Bethesda, MD 20814-2192
Telephone: (301) 493-8600

National Science Teachers Association
3140 N. Washington Boulevard
Arlington, VA 22201
Telephone: 1-800-722-NSTA

For information concerning ground-water educational materials contact:

Nebraska Groundwater Foundation
P.O. Box 22558
Lincoln, NE 68542-2558

## DEFINITIONS

**Aquifer** - An underground body of porous sand, gravel, or fractured rock filled with water and capable of supplying useful quantities of water to a well or spring.
**Crystalline Rock** - Igneous or metamorphic rock consisting of relatively large mineral grains.
**Freshwater** - Water that contains less than 1,000 milligrams per liter of dissolved solids.
**Ground Water** - Water beneath the land surface in the saturated zone.
**Ground-Water Discharge** - The flow or pumping of water from an aquifer.
**Ground-Water Recharge** - The addition of water to an aquifer.
**Infiltration** - Movement of water from the land surface into the soil.
**Permeability** - The capacity of porous rock for transmitting water.
**Public Supplies** - Water supplied for domestic, commercial, thermoelectric power, industrial, and other public uses.
**Saturated Zone** - Zone below the land surface where all the pores or fractures are filled with water.
**Surface Water** - Water on the Earth's surface.
**Unsaturated Zone** - The zone immediately below the land surface where the pores or fractures contain both water and air.
**Water Table** - The top of the water surface in the saturated zone of an unconfined aquifer.

## ACKNOWLEDGMENTS

The following individuals contributed to the development of this poster:

**Project Chief, Principal Author, and Layout:** Stephen Vandas, U.S. Geological Survey, Denver, Colorado

**Art Work:** Frank Farrar, Frank Farrar Graphics, Denver, Colorado, under contract to the American Water Resources Association

## U.S. DEPARTMENT OF THE INTERIOR

As the Nation's principal conservation agency, the U.S. Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This responsibility includes fostering the wisest use of our land and water resources, protecting our fish and wildlife, preserving the environmental and cultural values of our national parks and historical places, and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people. The Department also has a major responsibility for American Indian reservation communities and for people who live in island territories under United States administration.

MIDDLE SCHOOL EDITION



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## *Poster Series*

This poster is the fifth in a series of water-resources education posters developed through the Water Resources Education Initiative. The Water Resources Education Initiative is a cooperative effort between public and private education interests. Partners in the program include the U.S. Geological Survey and the U.S. Fish and Wildlife Service of the U.S. Department of the Interior, the U.S. Environmental Protection Agency, the U.S. Army Corps of Engineers, the Nebraska Groundwater Foundation, and the National Science Teachers Association.

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|---|---|---|
| **BIODIVERSITY** | **WATERSHEDS** | **ACID RAIN or HAZARDOUS MATERIAL** |
| **WETLANDS** | **WATER USE** | **WASTEWATER TREATMENT** |
| **OCEANS or NAVIGATION** | **GROUND WATER** | WATER QUALITY |

Water-resources topics of all completed posters are drawn in a cartoon format by the same cartoonist. Posters are available in color or black and white. The reverse sides of the color posters contain educational activities: one version for children in grades 3-5 and the other with activities for children in grades 6-8. The black-and-white posters are intended for coloring by children in grades K-5.

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# *ACTIVITY*

## *How Substances are Measured in Water*

### *Introduction*

Substances in water often occur in parts per million, parts per billion, or even parts per trillion. Water-quality laboratories can measure concentrations of substances at these levels, but what do these small concentrations mean? Developing an understanding of extremely large and small numbers is difficult. The following activity is designed to help students have an understanding of these extremely small concentrations.

### *Objective*

Students will be able to visualize extremely small concentrations of a material.

### *Materials* -- Each group will need:

1. One eye dropper;
2. Six small, clear plastic cups (the smaller the better); and
3. One 472-mL clear plastic cup filled 3/4 full of water.

Teacher needs: One bottle of food coloring.

### *Teacher Preparation*

1. This activity is designed for students in groups of three. However, if sufficient materials are not available, this activity can be done as a demonstration.
2. For each group, place one drop of food coloring in one of the small, clear plastic cups and fill the 472-mL cup 3/4 full of water.

### *Procedure*

1. Prior to conducting the activity, solicit responses from the students to the following questions:
   a. What is the largest number of things you can clearly visualize in your mind?
   b. Can you visualize a group of 1,000 people? Are you able to differentiate between 800 or 1,200 people from the 1,000?
2. Hand out one eye dropper; five small, clear plastic cups; one small clear plastic cup containing a drop of food coloring; and one 472-mL clear plastic cup filled 3/4 full of water to each group.
3. Explain that food coloring is usually a 10% solution; that is, 1 part (by volume) of food coloring dye is dissolved in 10 parts (by volume) of solution. For example, 1 mL of dye dissolved in 9 mL of water makes a total of 10 mL of 10% solution.

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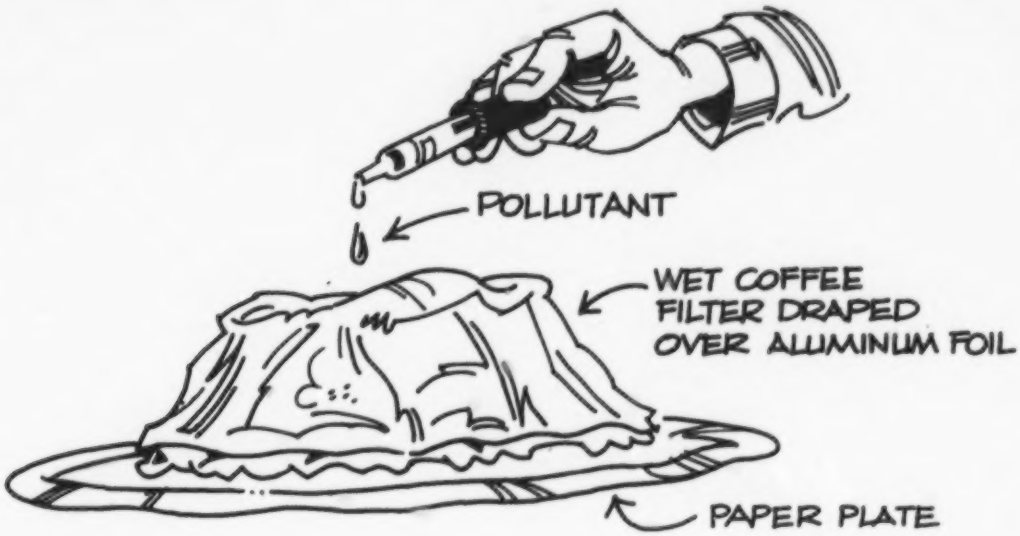
4. The instructor should place five drops of the food dye solution on the coffee filter. This solution represents pollution.




5. After 20 minutes, have the students examine the coffee filter. As a group, have the students observe, take notes, and make a diagram of the movement of the pollution using the 'X' and 'Y' markings as a reference.
6. Leave the coffee filter overnight and examine it again the next day.
7. Have the students answer the following questions:
   a. Describe what happened to the "pollution."
   b. What color of pollutant traveled the farthest from the point of contamination?
   c. Did any of the pollutants reach both imaginary wells?
   d. Did any of the pollutants travel uphill (against gravity)?
   e. What additional changes occurred when you compare the filter paper to the diagram you made on the first day?

## ***Discussion***

Have the students examine other group's coffee filters. How are they alike and how are they different?

1. Are pollutant paths relatively easy to predict?

Answer: No.

2. What are some factors that determine the direction and rates of movement of pollutants?

Answer: Soil types, rock types, shape of rock formation, and type of pollutants.

This activity was adapted from "Water Wisdom," published by the Massachusetts Water Resources Authority.

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What is water quality? To most students, water quality may suggest only "clean" water for drinking, swimming, and fishing. But to the farmer or manufacturer, water quality may have an entirely different meaning. One of the most important issues concerning the quality of water is how that water will be used. Water that is perfectly fine for irrigation might not be suitable for drinking or swimming.

The quality of water can change as it flows over the land surface as rivers, streams, lakes, or ponds (surface water), or under the land surface (ground water). Because surface and ground waters are interconnected in some areas, changes in the quality of surface water can affect the quality of the area's ground water, and vice versa. These changes in water quality may be due to natural factors or human activities.

As rock minerals come in contact with water, some dissolve and become part of the surface- or ground-water system. Other natural materials, such as soil or organic matter, become suspended in the water and move from one place to another. The effects of human activities on water may result from land disturbances, which increase the amount of rock minerals, soils, or organic matter available to be transported by and dissolved in water, or from the addition of human-made pollutants. When water is degraded to a point that affects its use for a particular purpose, it has become polluted.

Water pollution originates from two very different sources: point sources and nonpoint sources. This poster depicts human activities associated with point sources (labeled in yellow) and nonpoint sources (labeled in red). Also displayed is the movement of pollutants from their sources to surface and ground waters. The stream flowing from the mountains on the left-hand side of the poster represents clean water not affected by human activities. The river on the left-hand side of the poster receives pollutants from point sources (wastewater-treatment plant, storm drain, and factory). The quantities of pollutants entering this river are reduced as a result of pollution-control measures. The river on the right-hand side of the poster receives pollutants from many nonpoint sources (suburban lawn, parking lot, construction site, landfill, logging area, septic tank, and agricultural field). This river receives large amounts of pollution because there are no pollution controls. The bottom part of the poster displays the movement of water between streams and the underlying aquifer.

The poster is folded into 8.5" x 11" panels; the front and back sides can easily be photocopied.

## Point-Source Pollution

Pollution contributed to water from a discrete source, such as a pipe, ditch, tunnel, or well, are referred to as point sources. Generally, pollution from point sources are controlled to some degree by treatment technology. Municipal wastewater-treatment plants are one of the most common examples of treatment of point sources. While a municipal wastewater-treatment plant might receive water from many sources, it discharges into a water body at a single point.

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# *ACTIVITY*

## *Dispersion of Nonpoint Pollutants*

### *Introduction*

One of the difficult problems associated with the control of nonpoint sources of pollution is the identification of the source. Different soil types and the properties of underground rock formations affect how water pollutants travel. Pollutants can behave differently once they come in contact with soil. Biological processes can alter pollutants and their behavior. Many factors affect the physical, chemical, and biological makeup of water pollution.

### *Objective*

Students will become aware of the difficulty in determining the source of pollution.

### *Materials* -- Each group will need:

1. One coffee filter (15-20 cm in diameter);
2. One piece of aluminum foil 30 cm x 30 cm;
3. Water to wet filters;
4. Eye dropper; and
5. One paper plate approximately 25 cm in diameter for each group.

Teacher needs: one container each of red, yellow, and blue food dyes.

### *Teacher Preparation*

1. Prepare a mixture of one part each of the three food dyes and one part water in large enough quantity that each group of students can receive five drops of the resulting mixture. Do not tell the students what the mixture is.
2. Provide each group with one filter, one paper plate, and a piece of aluminum foil.

### *Procedure*

1. Divide students into groups of two. Have group members write their names on the coffee filter with a pencil. Then each group should place an 'X' and a 'Y' somewhere on the filter paper to represent imaginary wells.
2. Loosely crumple a piece of aluminum foil and place it in the middle of the paper plate.
3. Wet the coffee filter with water and drape it over the crumpled aluminum foil. The coffee filter represents soil on land surface. The aluminum foil represents bedrock on which the soil sits.

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4. Using the eye dropper, have one member from each group add 9 drops of water to the small cup containing the food coloring. Stir well. What is the concentration of the food coloring? This is 1 drop of the 10% food coloring in 10 drops of the new solution. Thus, the concentration is one-tenth of the original or 1 part in 100 (10 x 10) parts of solution.
5. Use the eye dropper to transfer one drop of the 1 part in 100 solution to a third small plastic cup. Add 9 drops of water to this solution. Stir well. The concentration has again been changed by a factor of ten. The new concentration is one-tenth of 1 part per 100 or 1 part in 1,000 (10 x 100) parts of solution.
6. Transfer one drop of the 1 part in 1,000 parts of solution into the next small plastic cup. Add 9 drops of water. Stir well. The new concentration is one part in 10,000 parts of solution.
7. Continue to dilute 1 drop of each solution by adding water as before to obtain 1 part in 100,000 and then 1 part in 1,000,000. Your final solution is one part per million.

## ***Interpretive Questions***

1. In which cup do you first observe no visual evidence that food coloring is present?

Possible Answer: This generally occurs in the final container, or one part per million.

2. Since you cannot see any evidence of color present in the cup, how do you know there is food coloring in the cup?

Possible Answer: The students placed it there.

3. Can you think of an experiment that you could do to prove there is food coloring present in each cup?

Possible Answers: 1) Compare each cup with a cup containing only water. 2) Place several drops of the water from each of the cups on a piece of filter paper and let it dry.

This activity was adapted from "Science Demonstration Projects in Drinking Water (Grades K-12)," published by the U.S. Environmental Protection Agency.

## ***ORDERING INFORMATION***

Single copies of the first four posters in the series (see Poster Series panel) and a limited supply of the "Water Quality" poster (color for grades 3-5 and 6-8 or black and white) can be obtained at no cost from the U.S. Geological Survey by writing to the following address:

U.S. Geological Survey
Box 25286
Denver Federal Center
Denver, CO 80225
Telephone: (303) 236-7477

In your letter, please identify the poster title and grade level desired.

Also, the poster entitled "Water: The Resource That Gets Used & Used & Used for Everything!" has been translated into Spanish. A limited supply of color or black-and-white copies can be obtained at no cost from the U.S. Geological Survey at the above address.

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## DEFINITIONS

**Aquifer** - An underground body of porous sand, gravel, or fractured rock filled with water and capable of supplying useful quantities of water to a well or spring.

**Erosion** - Process whereby materials of the Earth's crust are loosened, dissolved, or worn away and moved, usually by water or wind.

**Ground Water** - Water in the saturated zone beneath the Earth's surface.

**Nonpoint Source of Pollution** - Pollution from a broad area such as areas of fertilizer and pesticide application, rather than from point sources.

**Point Source of Pollution** - Pollution originating from a discrete source, such as the outflow from a pipe, ditch, tunnel, or well.

**Sediment** - Particles derived from rock or organic materials that have been transported by water or wind.

**Surface Water** - Water that is on the Earth's surface, such as rivers, streams, lakes, and reservoirs.

**Unconfined Aquifer** - An aquifer whose upper water surface (water table) is at atmospheric pressure and is free to rise and fall.

**Water Pollution** - Presence of any substance in water or addition of any substance to water that restricts the use of water.

**Water Table** - The top of the water surface in the saturated area of an aquifer.

## ACKNOWLEDGMENTS

The following individuals contributed to the development of this poster:

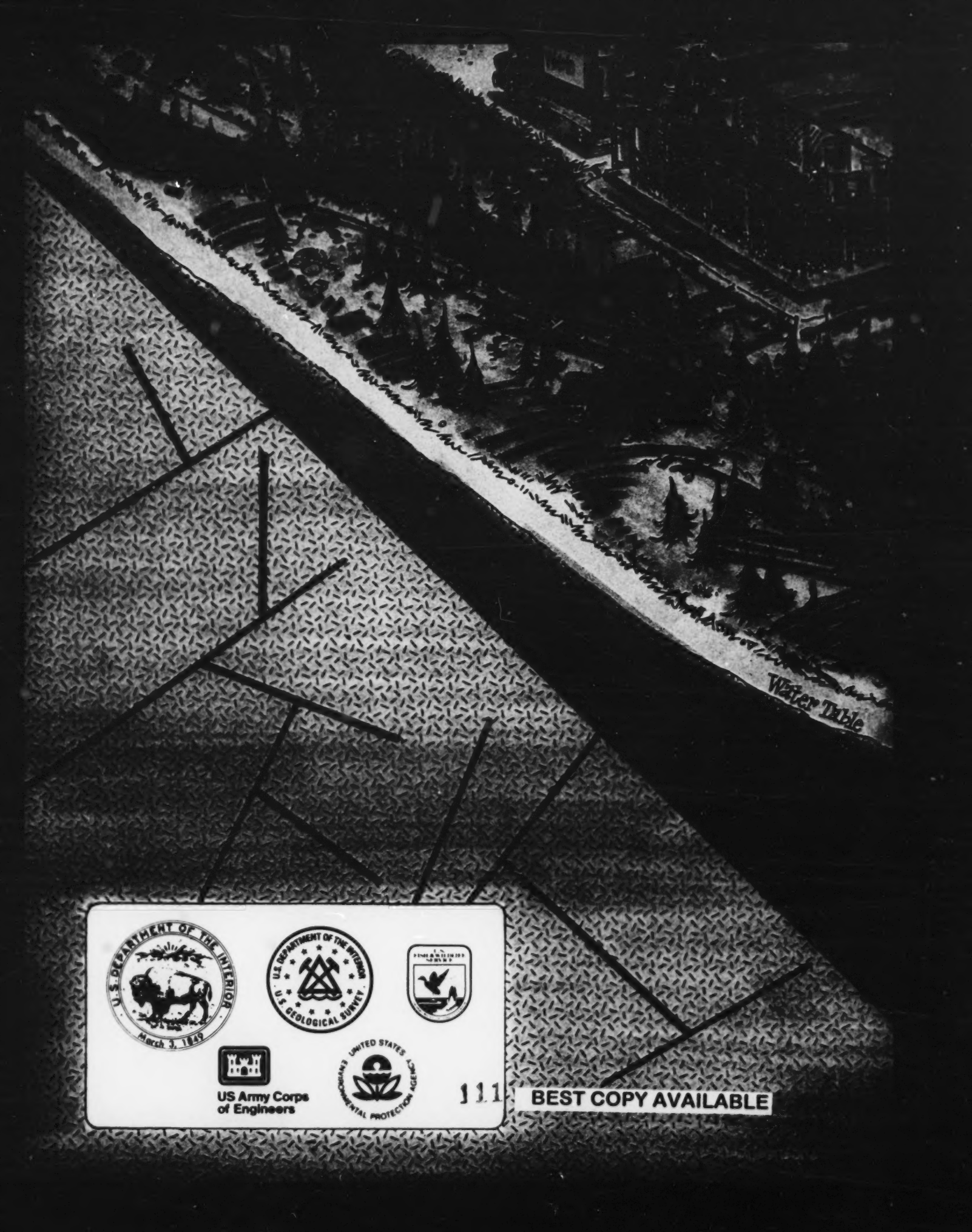
**Project Chief, Principal Author, and Layout:** Stephen Vandas, U.S. Geological Survey, Denver, Colorado

**Artwork:** Frank Farrar, Frank Farrar Graphics, Denver, Colorado, under contract to the National Science Teachers Association

## U.S. DEPARTMENT OF THE INTERIOR

As the Nation's principal conservation agency, the U.S. Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This responsibility includes fostering the wisest use of our land and water resources, protecting our fish and wildlife, preserving the environmental and cultural values of our national parks and historical places, and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people. The Department also has a major responsibility for Native American reservation communities and for people who live in island territories under United States administration.

**MIDDLE SCHOOL**




US Army Corps of Engineers

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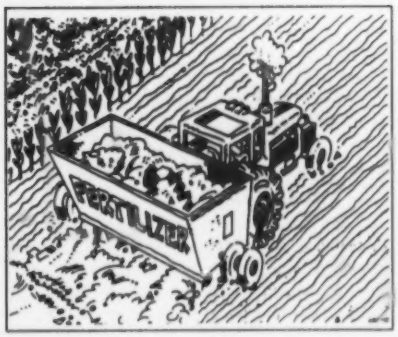
# Nonpoint-Source Pollution



Nonpoint source means that the pollution comes from a broad area, such as a large field that has been covered with fertilizer or pesticides. Excessive application of fertilizer or pesticides on agricultural lands or on lawns and gardens can create nonpoint sources. People who use fertilizers and pesticides must read labels to ensure that they are applying the materials properly.

A land-surface disturbance caused by humans, such as construction or logging, can create nonpoint sources of pollution. Pollution can occur when an increase in erosion caused by land disturbances produces large quantities of sediment, which is washed into rivers, streams, and lakes. Contamination can be reduced by preventing sediment from reaching waters through the implementation of erosion-control structures and the by planting and maintenance of soil-holding vegetation.

Disposal of garbage and trash at community landfills has the potential for polluting surface and ground water. Recycling of waste products such as oil, grease, plastics, paper, and aluminum reduces the potential for pollution from landfills. Many automobile products, such as gasoline and brake fluid, and household chemicals like cleaning solutions and turpentine, should not be placed in landfills but taken to special collection areas.

Oil and grease from automobiles, sand, gravel, salt, and other potential pollutants accumulate on parking lots and streets. Because very little water infiltrates into asphalt and concrete, the nonpoint-source pollutants that accumulate on them can be washed into surface waters during large storms. Prevention of this type of nonpoint pollution requires collection and treatment prior to discharge into surface waters.

## Hazardous Materials

Hazardous wastes produced as byproducts of manufacturing can affect water resources. Proper handling, storage, and disposal of hazardous materials is critical to the prevention of their entry into surface and ground water. This requires moving these materials to a safe storage location. What can individuals do to stop hazardous-waste pollution? One method is to stop dumping oil, cleaning liquids, or unknown substances on the ground or down the drain.

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MIDDLE SCHOOL EDITION

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## *Poster Series*

This poster is the sixth in a series of water-resources education posters developed through the Water Resources Education Initiative. The Water Resources Education Initiative is a cooperative effort between public and private education interests. Partners in the program include the U.S. Geological Survey and the U.S. Fish and Wildlife Service of the U.S. Department of the Interior, the U.S. Environmental Protection Agency, the U.S. Army Corps of Engineers, the Nebraska Groundwater Foundation, and the National Science Teachers Association.

The other completed posters in the series are entitled "Water: The Resource That Gets Used & Used & Used for Everything!", "How Do We Treat Our Wastewater?", "Wetlands: Water, Wildlife, Plants, & People!", "Ground Water: The Hidden Resource!", and "Water Quality: Potential Sources of Pollution." The posters in the series are designed to be joined to create a wall mural. A schematic of the wall mural including the topics for the completed and planned posters is displayed on this panel. The light-shaded spaces indicate the completed posters. The dark-shaded space represents this poster.

| | | |
|---|---|---|
| **BIODIVERSITY** | **WATERSHEDS** | **ACID RAIN or HAZARDOUS MATERIAL** |
| **WETLANDS** | **WATER USE** | **WASTEWATER TREATMENT** |
| OCEANS or NAVIGATION | **GROUND WATER** | **WATER QUALITY** |

Water-resources topics are drawn in a cartoon format by the same artist. Posters are available in color or black and white. The reverse side of the color posters contain educational activities: one version for children in grades 3–5 and the other with activities for children in grades 6–8. The black-and-white posters are intended for coloring by children in grades K–2.

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# ACTIVITY
# Kentucky River Map and Profile

## Introduction

Locks and dams are necessary structures for safe commercial and recreational travel on rivers with shallow water. On the adjacent panel is a map (aerial) view of the Kentucky River from south of Frankfort to Carrollton, Kentucky. Along the river are black T-shaped symbols showing the locations of the four sets of locks and dams currently used by commercial vessels. Most of the cargo carried on the Kentucky River is sand, gravel, and crushed rock that is pushed upstream in open hopper barges. Next to the map of the river is a profile, or side view, of the Kentucky River. The profile shows what the river, riverbed, dams, and navigation pools look like in cross section. The dams are numbered 1–4 on the map and profile.

## Objectives -- Students will:

1. Develop skills in reading maps and graphs.
2. Learn to correlate a map view with the same location in profile.
3. Apply math skills to practical situations.

## Materials

1. Map and profile of the Kentucky River.
2. Pencil and paper.

## Teacher Preparation

1. Display the poster "Navigation: Traveling the Water Highways" several days before conducting this activity.
2. Discuss the importance of locks and dams to commercial and recreational navigation. Explain the locking through process to students (see adjacent panel).

## Interpretive Questions

Use the map and river profile below to answer the following questions.

1. On the profile of the river are numbers written horizontally and vertically. What do the numbers 0 to 82 represent on the horizontal axis? (Answer: number of miles from the mouth of the river); What do the numbers 400 to 480 represent on the vertical axis? (Answer: elevation in feet above sea level).
2. What is the approximate distance between the mouth of the river at Carrollton and Dam No.4? (Answer: 68 river miles); between Lockport and Frankfort? (Answer: 38 river miles).
3. What is the difference in elevation between the pools behind Dams 2 and 4? (Answer: 27 feet).
4. In which direction does the Kentucky River flow? (Answer: north).
5. If a tow of coal barges is traveling 5 mph and each locking through takes 30 minutes, how long will it take to start at mile 82 and travel to Carrollton? (Answer: 18.4 hours); If you have to be at the coal terminal at Carrollton between 10:00 a.m. and 12:00 p.m. on a Tuesday, when would you have to leave? (Answer: between the hours of 3 p.m. and 5 p.m. on Monday); How many locks would you pass through? (Answer: 4 locks); What is the elevation change from start to finish? (Answer: approximately 50 feet); How many miles will the trip cover? (Answer: 82 miles); Would the trip take less time by plane? (Answer: yes); Why or why not? (Answer: a plane flies in a straight line and travels faster).

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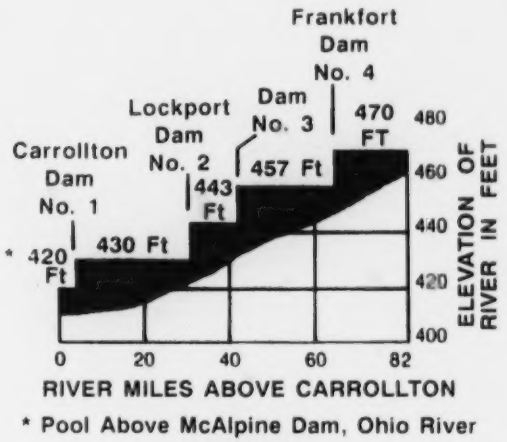
6. The Kentucky River looks like a winding snake from above. What makes it look so wiggly? (Answer: many bends in the river); Does the Ohio River look as crooked as the Kentucky River? (Answer: no); On which river do you think it would be easier to navigate a large tow? Why? (Answer: the Ohio River, because it is wider and straighter.)

## KENTUCKY RIVER MAP AND PROFILE

MAP




PROFILE

## ***DEFINITIONS***

**Barge** - Long, unpowered, flat-bottomed boat used to transport cargo on water; pushed or pulled by a powered boat.

**Dam** - Barrier built across a river to create a pool of water for navigation, flood control, water supply, or power generation.

**Domestic** - Within the United States.

**Dredge** - Machine equipped with a scooping or suction device used in deepening and widening harbors and waterways.

**Harbor** - Sheltered part of a water body deep enough to provide anchorage for ships or boats.

**Lock** - Walled navigational structure to allow raising or lowering vessels from one water level to another.

**Locking through** - Using a navigation lock to "step" up or down on a river.

**Port** - Region or city having a natural or artificial harbor with equipment, facilities, warehouses, and berths for ships taking on or discharging cargo or passengers.

**Sediment** - Solid material (gravel, sand, and silt) that settles to the bottom of a river.

**Towboat** - Powerful boat with a flat bottom and flat front used to push barges on rivers and other calm waterways.

**Tugboat** - Powerful boat with V-shaped bottom and rounded front used to pull barges on open water or maneuver ships in ports.

**Vessel** - Boat or ship intended for navigation on water.

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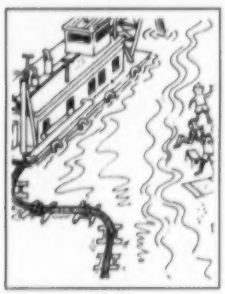
# Dredging:

Sediment (gravel, sand, and silt) is deposited naturally in a harbor or river channel when a river slows down. Accumulated sediment reduces the channel depth and can make the waterway unsafe for navigation. Mechanical and hydraulic dredges are used to deepen and widen channels filled with sediment and deposit the sediment in an approved location. Mechanical dredges shovel or scoop up bottom materials and place them on a barge or scow. The two hydraulic dredges shown on this poster use pumps to remove a mixture of water and sediment ("slurry") from the channel bottom. The HOPPER DREDGE is an ocean-going vessel used to dredge sediment from the bottom of a deep-water channel or coastal harbor. Dredged material is stored in "hopper bins" inside the ship before disposal in the open sea or other location.

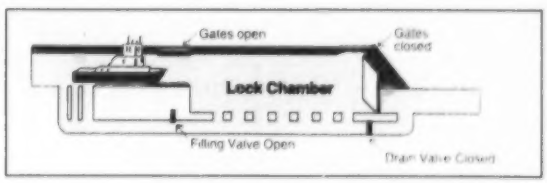


PIPELINE DREDGE: Vessel commonly used to dredge sediment from the bottom of shallow rivers or calm coastal waters. Dredged material is pumped from the river or ocean bottom and flows through a floating pipeline to shore. The dredged material commonly is used to restore eroded beaches.

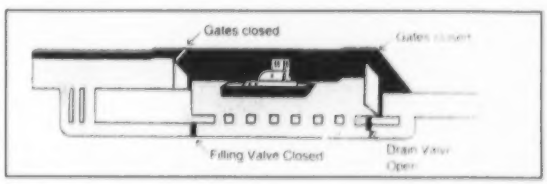
# Locks and Dams:

Dams are built on shallow rivers to hold back water and form deeper navigation "pools." Most pools in the United States are maintained at a constant minimum water depth of 9 feet for safe navigation. Dams make it necessary for river vessels to use a series of locks to "step" up or down the river from one water level to another. The three steps in the "LOCKING THROUGH" process are shown below.

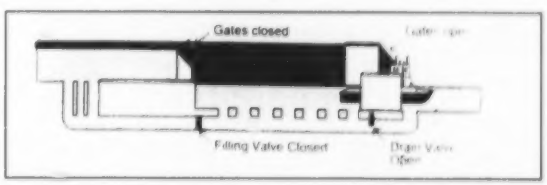
For a boat going downstream, the lock is first filled by opening the filling valve. The drain valve and upstream and downstream gates are closed, so the level of the water in the chamber rises to the upstream level. The upstream gate opens and the boat moves in.




To lower the boat, the gates are closed behind it, the filling valve is closed, and the drain valve is opened. The higher water in the lock chamber drains to the downstream level within minutes.




The downstream gate is then opened and the boat moves out on the lower water level. The process is reversed for a boat going upstream.



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US Army Corps
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# ACTIVITY
# Comparing Different Modes of Transportation

## Introduction

Transportation of domestic cargo by barge is relatively slow, but it is efficient and cost effective for moving large amounts of goods from one place to another. A comparison of the cargo capacities of a barge, jumbo hopper rail car, and large semitrailer truck is shown below.

BARGE
1500 TON
52,500 BUSHELS
453,600 GALLONS

JUMBO HOPPER CAR
100 TON
3,500 BUSHELS
30,240 GALLONS

LARGE SEMI
25 TON
910 BUSHELS
7,865 GALLONS

## Objectives -- Students will:

1. Calculate equivalent cargo capacities and ton-miles of traffic.
2. Compare cargo capacities of barges, trains, and trucks.

## Materials

1. Pencil and paper.
2. Calculator (optional).

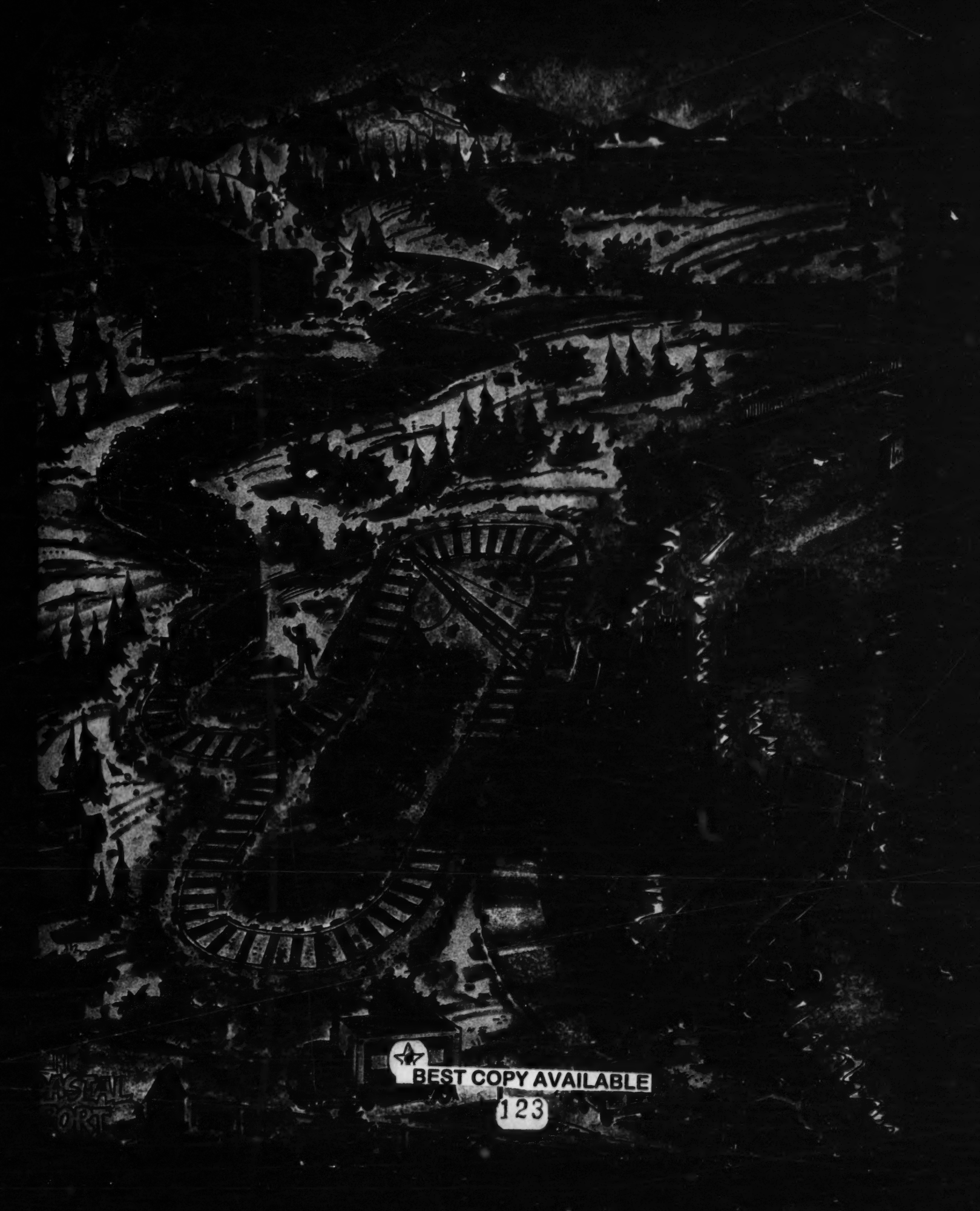
## Teacher Preparation

1. Display the poster "Navigation: Traveling the Water Highways" several days before conducting this activity.
2. Discuss the different ways that people and cargo travel, emphasizing the importance of navigation to our Nation's economy.

## Interpretive Questions

Use the tonnage information above to answer the following questions:

1. How many jumbo hopper rail cars would be needed to carry the same weight of coal as one barge? (Answer: 15); How many trucks would be needed to carry the same weight of coal as one barge? (Answer: 58).
2. It can be seen from the comparison above that the cargo capacities of barges, rail cars, and trucks differ greatly. The speed at which these different vehicles travel also varies. Tows travel at about 5 mph by river. A train moves along a railroad track at approximately 30 mph. Trucks traveling in a convoy usually travel at about 55 mph. Assuming a distance of 1,700 miles between St. Paul, Minnesota, and New Orleans, Louisiana, how many hours would it take for a barge, truck, and train to travel the distance? How many days? (Answers: barge: 340 hours, 14+ days; truck: 31 hours, 1+ days; train: 56–57 hours, 2+ days).
3. One "ton-mile" equals 1 ton of cargo moved a distance of 1 mile. How many ton-miles of traffic are produced by transporting 1,500 tons (one full barge) a distance of 1,700 miles from St. Paul to New Orleans? (Answer: 2,550,000 ton-miles).
4. One hundred jumbo hopper cars join together to form a "unit train." How many tons of grain can a unit train carry? (Answer: 10,000 tons).



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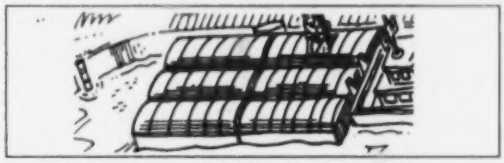
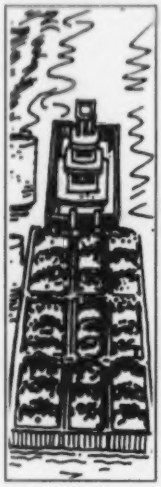
# River Vessels:

The most common way of transporting products on rivers is by TOW. A tow consists of one TOWBOAT and one or more BARGEs. Towboats push different kinds of barges, depending on the cargo. Three of the four basic types of barges are shown below. The fourth type is a DECK barge, which carries almost any kind of equipment, materials, or products that can be tied down and do not need protection from the weather.

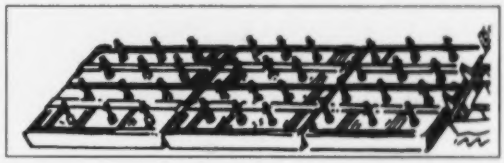
COVERED DRY CARGO barge: Carries bulky solid cargo, such as dry cement, fertilizer, and farm products (corn, wheat, and soybeans) that need protection from the weather.





OPEN HOPPER barge: Holds bulky products, such as sand, gravel, or coal, that do not need protection from the weather.

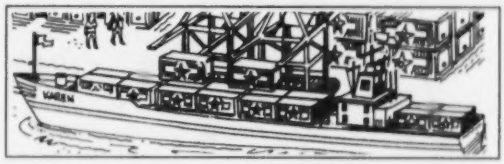
LIQUID CARGO (TANK) barge: Transports liquid products such as chemicals, petroleum, oil, and molasses.

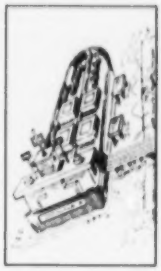


# Ocean-Going Vessels:

Many products are traded with other countries by using deep-water ocean ports. Products that come into the country are called imports and those that are shipped to other countries are called exports. Trucks, trains, tows, and pipelines transport products into and out of ocean ports. Some of the large, ocean-going vessels in the deep-water harbor are shown below.

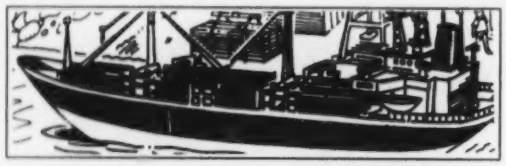
CONTAINERSHIP: Transports products stored in 20- to 45-foot-long containers that are stacked inside the ship and outside on the deck. Some ships carry as many as 5,000 containers.

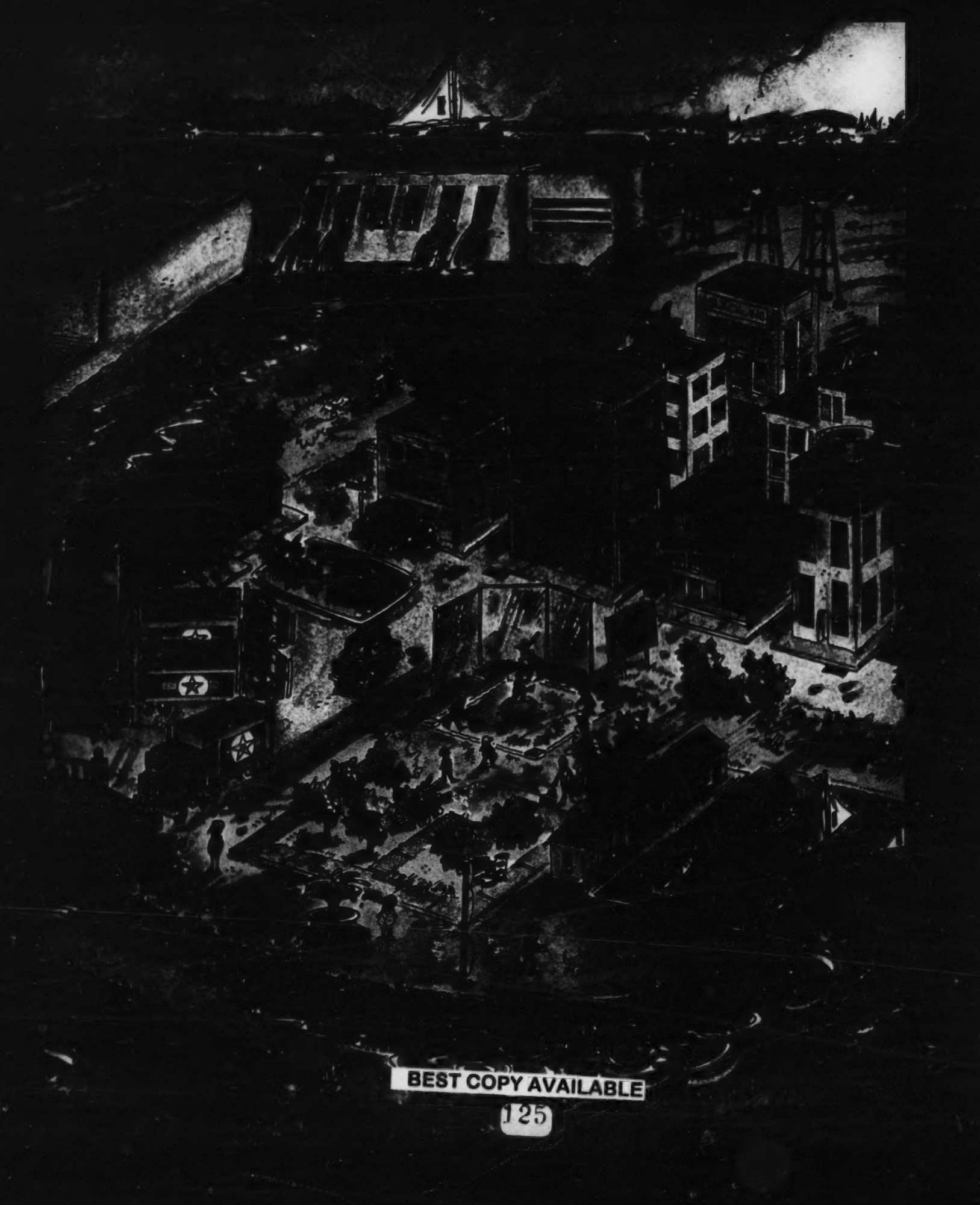




TANKER ship: Holds chemicals, petroleum products, oil, and other liquids.

BREAK BULK ship: Carries bulky cargo such as lumber, packages of fertilizer, and boxes of fruit. Break bulk cargo is usually loaded and unloaded on portable platforms ("pallets").





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**NAVIGATION** is travel or transportation over water. Many different kinds of boats and ships are used on rivers and oceans to move people and products from one place to another.

Navigation was extremely important for foreign and domestic trade and travel in the early days of our country before cars, trucks, trains, and airplanes were invented. In those days, rivers were used as "roads" to connect inland settlements to river and coastal ports. Communities established at these commercial ports became important economic, cultural, and social hubs in the development of our Nation.

Many of the products we use and eat today are still transported by vessels on deep oceans and relatively shallow rivers or inland waterways. Towboats push barges (labeled in red) loaded with products such as grain, coal, and petroleum up and down rivers to loading and unloading facilities. Activities at a deep-water coastal port might include the loading or unloading of large commercial ocean-going vessels with lumber, oil, or cargo in large containers. Ocean-going vessels (labeled in yellow) maneuver in deep coastal harbors with the help of tugboats.

Navigation activities in the United States take place at more than 400 ports and along more than 25,000 miles of waterways. Some of the ports and waterways making up the extensive navigation network in this country are shown on the map below. Most rivers in the western part of the United States are not used for commercial navigation. Some of these rivers are used instead for recreation, irrigation, and generation of electricity. Shallow harbors or rivers are made safe for navigation by dredging or the construction of locks and dams.

## Ports and Navigable Waterways of the United States

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## ORDERING INFORMATION

Copies of the first five posters in the series (see Poster Series panel) and the Navigation poster (color for grades 3–5 and 6–8 or black and white) can be obtained at no cost from the U.S. Geological Survey. Write to the address below and specify the poster title(s) and grade level(s) desired. A limited number of color and black-and-white posters entitled "Water: The Resource That Gets Used & Used & Used for Everything!" are also available in Spanish by writing to the address below.

U.S. Geological Survey
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Denver Federal Center
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## U.S. ARMY CORPS of ENGINEERS

The U.S. Army Corps of Engineers is responsible for the operation and maintenance of the Nation's waterways to ensure efficient and safe passage of commercial and recreational vessels. The Corps' navigation projects play an integral role in the Nation's economy by providing efficient means by which commercial shippers can economically transport foreign and domestic products.

## U.S. DEPARTMENT of the INTERIOR

As the Nation's principal conservation agency, the U.S. Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This responsibility includes fostering the wise use of our land and water resources, protecting our fish and wildlife, preserving the environmental and cultural values of our national parks and historical places, and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people. The Department also has a major responsibility for American Indian reservation communities and for people who live in island territories under United States administration.

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